Iowa State University
Digital Repository

Retrospective Theses and Dissertations

Iowa State University Capstones, Theses and Dissertations

2008

Essays in macroeconomics, international trade and the environment

Shiva Sikdar
Iowa State University

Follow this and additional works at: https://lib.dr.iastate.edu/rtd

Part of the Economic Theory Commons

Recommended Citation
Sikdar, Shiva, "Essays in macroeconomics, international trade and the environment" (2008). *Retrospective Theses and Dissertations*. 15833.
https://lib.dr.iastate.edu/rtd/15833

This Dissertation is brought to you for free and open access by the Iowa State University Capstones, Theses and Dissertations at Iowa State University Digital Repository. It has been accepted for inclusion in Retrospective Theses and Dissertations by an authorized administrator of Iowa State University Digital Repository. For more information, please contact digirep@iastate.edu.

المنارة للاستشارات

www.manaraa.com

Essays in macroeconomics, international trade and the environment

by

Shiva Sikdar

A dissertation submitted to the graduate faculty

in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

Major: Economics

Program of Study Committee:
Harvey E. Lapan, Co-major Professor
P. Marcelo Oviedo, Co-major Professor
Joydeep Bhattacharya
Arnold R. Cowan
Jinhua Zhao

Iowa State University

Ames, Iowa

2008

Copyright © Shiva Sikdar, 2008. All rights reserved.

www.manaraa.com

UMI Number: 3316189

INFORMATION TO USERS

The quality of this reproduction is dependent upon the quality of the copy submitted. Broken or indistinct print, colored or poor quality illustrations and photographs, print bleed-through, substandard margins, and improper alignment can adversely affect reproduction.

In the unlikely event that the author did not send a complete manuscript and there are missing pages, these will be noted. Also, if unauthorized copyright material had to be removed, a note will indicate the deletion.

UMI®

UMI Microform 3316189
Copyright 2008 by ProQuest LLC
All rights reserved. This microform edition is protected against unauthorized copying under Title 17, United States Code.

ProQuest LLC
789 East Eisenhower Parkway
P.O. Box 1346
Ann Arbor, MI 48106-1346

TABLE OF CONTENTS

للاستشارات المنارة

www.manaraa.com

المنارة للاستشارات
www.manaraa.com

www.manaraa.com

LIST OF TABLES

www.manaraa.com

LIST OF FIGURES

المنارة للاستشارات

www.manaraa.com

ACKNOWLEDGEMENTS

I would like to take this opportunity to express my gratitude to my co-major professors, Harvey E. Lapan and P. Marcelo Oviedo, for their guidance, patience and support throughout this research and the writing of this dissertation. I am indebted to my committee members, Joydeep Bhattacharya, Arnie Cownan and Jinhua Zhao, for their insightful comments on this work. I would also like to thank Rajesh Singh for his suggestions regarding this dissertation.

المنارة للاستشارات

www.manaraa.com

ABSTRACT

This dissertation addresses the problem of optimal recapitalization of banking sectors after banking crises and analyzes the effect of trade liberalization on environmental policy and welfare in a strategic setting in the presence of transboundary pollution.

Government-financed bank restructuring programs, occasionally costing up to 50% of GDP, have commonly been used to resolve banking crises. In Chapter 2 we analyze the Ramsey-optimal paths of bank recapitalization programs that weigh recapitalization benefits and costs under different financing options. In our model bank credit is essential, due to a working capital constraint on firms, and banks are financial intermediaries that borrow from households and lend to firms. A banking crisis produces a disruption of credit and a fall in output equivalent to those in developing countries affected by banking crises. Full recapitalization of the banking system immediately after the crisis is optimal only if international credit is available. One-shot recapitalization is not optimal with domestically-financed programs, even if the government has access to non-distortionary taxes. The welfare cost of a crisis is substantial: the equivalent permanent decline in the no-crisis steady state consumption ranges between 0.51% and 0.65%, depending on the source of financing the recapitalization program.

In Chapter 3 we analyze the effects of free trade on environmental policies in a strategic setting when there is transboundary pollution. Trade liberalization can result in a race to the bottom in environmental outcomes, which makes *both* countries worse off. In our model it is not the terms of trade motive, but the incentive, in a strategic setting, to reduce the incidence of transboundary pollution, that drives countries to relax domestic environmental policy. When command and control policies such as quotas are used instead of taxes, countries are unable to influence foreign emissions by strategic choice of domestic policy; hence, there is

www.manaraa.com

no race to the bottom. However, when permits are tradable across countries, unless pollution is a pure global public bad, there is a race to the bottom in environmental policy. In the free trade equilibrium, internationally nontradable quotas result in the lowest pollution level, while the relative ranking of pollution in the internationally tradable quota equilibrium and the tax equilibrium depends on the relative magnitudes of domestic and transboundary pollution and the relative slopes of the demand and supply schedules. The nontradable quota equilibrium *strictly* welfare-dominates the tax equilibrium.

Chapter 4 extends the model of the previous chapter to explicitly model differences between countries that may lead to trade in equilibrium. We analyze the effect of trade liberalization on pollution policy and welfare in the presence of both the terms of trade motives and the transboundary pollution effect. We find that, when countries use taxes to regulate pollution, the importer of the polluting good unambiguously lowers its tax as a result of trade liberalization, while the exporter of the polluting good reduces (increases) its tax if the transboundary pollution (terms of trade) effect dominates. It is possible for both countries to be worse off due to trade liberalization. When the only source of comparative advantage is a difference in the preference towards pollution, then aggregate (world) welfare is higher under free trade as compared to autarky if countries use quotas to regulate pollution, but is lower under free trade relative to autarky if the policy instrument in both countries is a pollution tax.

المنارة للاستشارات
www.manaraa.com

CHAPTER 1. GENERAL INTRODUCTION

This dissertation analyzes the optimal path of banking sector recapitalization programs in the aftermath of a banking crisis and the effects of a movement from autarky to free trade on domestic environmental policy, pollution and welfare when, in the presence of a transboundary pollution externality, countries strategically set their domestic environmental policies.

Banking sector problems leading to bank insolvencies have been frequent in recent decades in developed and developing countries. Given the serious macroeconomic consequences of banking crises, governments often end up recapitalizing the banking sector after a crisis. The high fiscal cost of such programs warrants a careful analysis of the optimal path of recapitalization given the financing options available to the government. In Chapter 2 we analyze the optimal path of a bank recapitalization program that weights the recapitalization benefits and the program's costs. We focus on the aftermath of a banking crisis when a large fraction of the banking capital stock has already been eroded and the banking system is providing just a fraction of the efficient level of financial intermediation.

In our model, banks accept deposits from households and lend to firms. Firms need to borrow from banks due to a working capital constraint which requires them to pay for their input before the sales of their product. Following the empirical literature, we define a banking crisis as a decline in the bank capital stock, which leads to a decline in the loan supply. The consequent rise in the interest rate on loans leads firms to reduce their demand for inputs, which, in turn, causes a decline in employment and production.

We characterize optimal bank recapitalization programs by formulating a Ramsey planner's problem, where the planner chooses a bank recapitalization program that can be implemented as a competitive equilibrium. The optimal program depends on the financing options available

المنارة للاستشارات
www.manaraa.com

to the government.

When the government can borrow from international debt markets to finance the recapitalization program, it is able to recapitalize the banking system immediately and achieve perfect consumption smoothing. One-shot recapitalization is not optimal with domestically-financed programs, even if the government has access to non-distortionary taxes. The welfare cost of a crisis is substantial: the equivalent permanent decline in the no-crisis steady state consumption is 0.51% when the government has access to international debt and 0.63% (0.65%) when the recapitalization program is financed by lump-sum (labor-income) taxes.

A serious concern about the relationship between trade and environmental policy is that these two issues have usually been dealt with separately in bilateral or multilateral agreements. Chapter 3 explores the effects of trade liberalization on environmental outcomes and welfare, in the presence of transboundary pollution, when environmental policy is set non-cooperatively. We use a two good, two country trade model in which production of one of the goods generates pollution as a by-product. Pollution reduces welfare in both countries, but does not affect the production possibility set. We compare different policy instruments within this framework when countries strategically set environmental policies.

We find that, in the symmetric equilibrium, if governments use taxes, the movement from autarky to free trade can result in a race to the bottom in environmental taxes that results in *both* countries being worse off under free trade relative to autarky. The motive behind the under-regulation of the polluting sector is not the terms of trade motive but the transboundary pollution effect, i.e., the incentive to under-regulate domestic pollution to reduce the incidence of transboundary pollution from abroad, which partly offsets the benefits of tighter domestic pollution policies.

When the policy instrument in both countries is a production or pollution limit, then, in the symmetric equilibrium, changes in domestic policy do not affect foreign production (hence, foreign emissions) and there is no incentive to distort domestic policy. Thus, there is no race to the bottom in environmental policy.

However, if international trade in emission permits is allowed, then a race to the bottom

المنارة للاستشارات
www.manaraa.com

in environmental policies will occur if pollution is not a pure global public bad, but not when pollution is a pure global public bad. In the symmetric free trade equilibrium, pollution is lowest with internationally nontradable quotas. We find that the internationally nontradable emissions quota equilibrium is strictly welfare-superior to the emissions tax equilibrium. The welfare ranking of the internationally tradable quota equilibrium and the tax equilibrium depends on the severity of transboundary pollution and the relative slopes of the demand and supply schedules.

We then generalize the model to allow for production of both goods to generate pollution as a by-product, the possibility of substitutability between polluting and non-polluting inputs, and abatement. The results derived earlier in the chapter continue to hold.

Chapter 4 extends the analysis of Chapter 3 and explicitly models differences between the countries with respect to their production possibility functions and preferences. We model different scenarios that may lead to equilibrium trade between the countries and analyze the effect of a movement from autarky to free trade when countries strategically set domestic policies in the presence of a transboundary pollution externality.

The transboundary pollution effect tends to lower the environmental tax, irrespective of the pattern of trade while the terms of trade effect depends on the trade pattern. We find that, in the presence of terms of trade effects, the importer of the polluting good lowers its domestic environmental tax under free trade relative to autarky; this is because, both the terms of trade effect and the transboundary pollution effect reinforce each other to reduce the domestic tax. However, in the exporter of the polluting good, the terms of trade and transboundary pollution effect work in opposite directions. So, the effect of trade liberalization on the environmental tax depends on which of the two effects dominates. The welfare effect of trade liberalization depends on whether the gains from the opportunity of trade dominates the loss due to increased pollution.

We then analyze the case when countries use quotas to regulate pollution. Production of the polluting good declines in the importing country and it increases in the exporter of the polluting good due to trade liberalization. The difference in the pollution intensity between

المنارة للاستشارات
www.manaraa.com

the two countries and the severity of transboundary pollution, together determine whether pollution increases or decreases due to a movement from autarky to free trade.

When pollution is a pure global public bad and the only difference between countries is their preference towards pollution, then the country with a higher marginal disutility from pollution unambiguously *lowers* its pollution tax due to trade liberalization, while the other country may also reduce its tax. Production of the polluting good in both countries is higher under free trade relative to autarky and so is pollution. The country with preference for cleaner environment is worse off and the other country may be worse off, but aggregate (world) welfare is lower as a result of a movement from autarky to free trade, when countries use taxes to regulate domestic pollution. However, if governments use command and control policies (quotas) to regulate pollution, there is no effect on pollution and total world production of the polluting good when countries move from from autarky to free trade. The country with lower (higher) marginal disutility from pollution is better (worse) off, but aggregate (world) welfare is unambiguously higher under free trade as compared to autarky. Hence, from the aggregate perspective, the free trade quota equilibrium is welfare-superior to the tax equilibrium.

Chapter 5 provides a summary and brief concluding remarks.

المنارة للاستشارات
www.manaraa.com

CHAPTER 2. OPTIMAL BANKING SECTOR RECAPITALIZATION

(This chapter is a close version of Oviedo and Sikdar (2007).)

2.1 Introduction

Banking sector problems leading to bank insolvencies have been frequent in recent decades in developed and developing countries alike. Lindgreen et al. (1996) report that, between 1980 and 1996, 133 of the 181 of IMF's member countries have experienced significant banking sector problems, including numerous banking crises. Along the same lines, Caprio and Klingebiel (2003) report that between the late 1970s and 2002, there were 117 systemic banking crises - defined as much or all of the banking capital being exhausted - in 93 countries.

The macroeconomic consequences of banking crises are well documented. In their study of 36 banking crises in 35 countries between 1980 and 1995, Demiirgüç-Kunt et al. (2006) define a "banking crisis as a period in which segments of the banking system become illiquid or insolvent" and find that banking crises commonly cause sharp declines in output growth rates. Moreover, financial distress helps in propagating the adverse shocks to the real sectors of the economy when banks reduce lending to creditworthy borrowers. Likewise, the harmful macroeconomic consequences of banking sector problems have been identified in the U.S. economic history during periods of banking-sector distress. Romer (1993), for instance, suggests that "...the banking crises of 1931 and later were a crucial cause of the deepening and sustaining of the Great Depression in the United States ...".

The real effects of banking crises are worse for sectors that have very limited alternatives to bank financing, something that applies across the board in developing countries. The evidence in this regard found by Dell'Ariccia et al. (2005) lead them to subscribe to the view that banks

www.manaraa.com

need to be supported during distress in order to prevent a vicious circle in which banking distress and economic contraction reinforce each other.

A sound banking system is oftentimes considered a public good that is essential for macroeconomic stability, so it is not surprising to see governments get drawn into the costly process of recapitalizing bankrupt banks in the aftermath of a banking crisis. Honohan and Klingebiel (2000) find that in their sample of 40 crisis-countries, governments end up bearing most of the direct costs of the crises. Fiscal resolution costs average about 13% of GDP in general, and 14.3% in developing countries. However, these fiscal costs are, at best, a lower bound on the resources involved in remedying the effects of a banking crisis since actual costs are substantially higher due to indirect methods of government assistance, and the buildup of direct liabilities from state owned banks and of contingent liabilities from deposit and credit guarantees (see Daniel et al. (1997)). According to Caprio and Klingebiel (1996), an overall estimate of the amount of resources involved in bank restructuring programs is between 10 and 20% of GDP in most cases and occasionally as much as 40-55% of GDP.

Not only is the expenditure side of the fiscal balance affected by a banking crisis, the revenue side is hit as well. The general slowdown of the economy following a banking crisis substantially reduces tax bases and therefore tax revenues. All in all, a banking crisis is a costly (and recurrent in some countries) phenomenon that produces serious adverse macroeconomic consequences and has enormous negative effects on fiscal balances, mostly because the public-good aspect of a well functioning banking system leads the government to restore the system after a crisis.

This chapter characterizes Ramsey-optimal bank restructuring programs from the public finance viewpoint and seeks to answer the following question: *once a government decides to recapitalize a bankrupt banking sector, what is the optimal path of a program that weights the recapitalization benefits and the program's costs?* To the best of our knowledge, this is the first attempt at *formally* analyzing the problem of recapitalizing a bankrupt banking system in the aftermath of a banking crisis that takes into account the fact that the costs of funding such a program depend on the government's sources of funding the program.

المنارة للاستشارات
www.manaraa.com

To focus on the public finance aspect of the problem, we abstract from the causes of the banking crises and the moral hazard problems arising from government intervention in a financial system. Instead, we analyze the resolution of a banking crisis once it has occurred and the government has already decided to restructure the economy's bankrupt banking system.[1] Thus, instead of focusing on panics or serious liquidity dry-outs, we focus on the aftermath of a banking crisis when a large fraction of the banking capital stock has already been eroded and the banking system is providing just a fraction of the efficient level of financial intermediation. By recapitalizing undercapitalized banks we refer to the injection of banking capital that restores the ability of these banks to intermediate financial credit at an efficient level.

We conduct our analysis by modeling a perfect foresight economy that is hit by an unforeseen banking crisis. Following the empirical literature, we define a banking crisis as an event in which much or all of the bank capital is depleted (see Caprio and Klingebiel (2003)). We model banks following Cole and Ohanian (2000) and, in our model, the banking sector is a financial intermediary that borrows from households and lends to firms. Bank deposits are the only saving mechanism available to households; banks intermediate these deposits to lend to the firms, which face a working-capital constraint that requires them to pay their wage bill before cashing their sales. Government outlays comprise of a fixed government consumption and, in the event of a banking crisis, the costs of recapitalizing the banking system.

The mechanism through which output and employment plummet in the aftermath of a crisis is as follows. A decline in the stock of banking capital leads to a decline in the loan supply. The consequent rise in the interest rate on working-capital loans leads firms to reduce their demand for inputs, which in turn causes a decline in production. For similar reasons, replenishing bank capital raises the volume of financial intermediation, increases the loan supply, reduces interest rates, and thereby stimulates output and employment in the aftermath of a crisis.

To characterize efficient programs, we formulate a Ramsey planner's problem in which the government has to choose a bank restructuring program that can be implemented as a competitive equilibrium. The government's objective, in the aftermath of a banking crisis, is

[1] Although we abstract from the these moral hazard problems, it must be said that recapitalizing undercapitalized banks does not necessarily mean maintaining the management nor the ownership of the bank charter.

المنارة للاستشارات

www.manaraa.com

to endow the economy with the benefits of a well running banking system but internalizing the direct and indirect resource costs of the recapitalization program. Thus, the optimal program hinges upon the means by which the government funds it. In particular, we characterize the optimal bank restructuring program under three alternative sources of public revenue. In the first case, the rebuilding of the banking sector can only be financed with distortionary labor taxes. In the second case, we allow the government to resort to lump-sum taxes to fund the restructuring program. And in the third case, while we rule out lump-sum taxes, the government has access to international debt markets to finance the recapitalization program.

We find that only when the government has access to international credit, is it optimal to *fully* recapitalize the banking system in the period following the crisis. With domestically-financed recapitalization programs, however, even when non-distortionary taxes are available, it is never optimal to recapitalize the banks in one period. Our results contrast those found in the literature dealing with the microeconomic aspects of bank restructuring policy which, by abstracting from the public finance aspect of the problem, *always* recommends an immediate, full recapitalization of banks to prevent further loss of confidence in the problem-ridden banking system.

To fix ideas about our results, consider the case where the government has access to international debt to fund the bank recapitalization program. The banking system is bankrupt in the initial period and the loss of banking capital submerges the economy into a recession in that period. By borrowing abroad, the government is able to secure the funds necessary to recapitalize the banks, so the economy quickly recovers from the recession in the next period. Moreover, using international debt, the government can also provide subsidies to the households to alleviate the effects of the recession until the banking crisis is resolved in the next period. From then on it is optimal to smooth out the distortionary taxes so that the debt incurred to finance the bank restructuring program is rolled over forever. Thus, with access to international credit, full, one-period recapitalization of the banks is optimal.

Results are different when the economy lacks access to external credit to finance the recapitalization program and the government has to resort to domestic taxation. Assume first

www.manaraa.com

that lump-sum taxes are available. Fully recapitalizing the banks in one period is not optimal because lump-sum taxes, despite being non-distortionary, withdraw large amounts of resources from the private sector which causes a decline in consumption and hence in welfare. Consumption smoothing thus entails that the government replenish the stock of banking capital gradually. When only distortionary labor taxes are available, recapitalization of the bankrupt banking sector is even slower. This is because labor-income taxation, apart from withdrawing resources from consumption, distorts the consumption-leisure choice of the households.

Quantitative results from the numerical solution of the model, calibrated to match basic macroeconomic ratios in developing countries, indicate the following: a banking crisis results in a welfare loss equivalent to a 5.51% permanent decline in the no-crisis steady state consumption if the government does not intervene. When the recapitalization program is financed by labor-income taxes, the economy reaches the new steady state in 23 periods, and the resulting welfare loss is 0.65%. With lump-sum taxes available to the government, convergence to the new steady state occurs in 22 periods, with the welfare loss being reduced to 0.63%. Access to international debt mitigates the above welfare loss to 0.51% reduction in the no-crisis steady state consumption and the new steady state is reached in two periods.

The rest of the chapter is organized as follows. In the next section we present the perfect-foresight, decentralized, general equilibrium model. We formulate the corresponding Ramsey problem in Section 2.3. Section 2.4 presents the quantitative results and Section 2.5 concludes.

2.2 The Model

We model a perfect-foresight economy with four types of agents: households, goods-producing firms, banks and the government. Firms, which along with the banks, are owned by the households, need working capital to pay their wage bill before cashing their output's sale proceeds. Banks intermediate by borrowing savings from households and by lending working capital to the firms. Firms' technology combine capital and labor to produce output, while banks' technology uses deposits and bank capital to produce loans.

To guarantee the consistency of the intertemporal household's deposit decisions with the

المنارة للاستشارات
www.manaraa.com

(essentially) atemporal banks' and firms' optimization problems involving credit, we follow Neumeyer and Perri (2005) to assume that there are two times within each period t. One at the beginning of the period, denoted by t^-, and one at the end of the period, denoted by t^+. We assume that t^+ and $(t+1)^-$ are arbitrarily close. At t^- banks accept deposits, d_t, from the households and use them along with the stock of banking capital, A_t, to produce loans instantaneously. Firms need to borrow from the banks to fulfill their working capital constraint at t^-. Labor is hired and paid using loans from the banks at t^-. Firms use the hired labor and the capital stock to produce the final good which becomes available at t^+. Firms repay their loans along with interest, $R_{bt}b_t$, to the banks at t^+. Firms' and banks' profits, π_t^f and π_t^b respectively, along with the gross interest income, $R_t d_t$, are distributed to the households; the household allocates these resources between consumption, c_t, and savings, in the form of one-period deposits in the banks, d_{t+1}. Within each period, the government collects taxes and uses the proceeds to pay for its outlays which include the fixed government expenditure, $\bar{g}$, and may also include other transfers related to the recapitalization of the banking system.

2.2.1 Households

The representative household has an infinite life and chooses sequences of consumption, labor supply, and bank deposits, $\{c_t, h_t, d_{t+1}\}_{t=0}^{\infty}$, to maximize the following lifetime discounted utility

$$\sum_{t=0}^{\infty} \beta^t U(c_t, l_t) \tag{2.1}$$

where β is a standard discount factor and U is a strictly concave, increasing, and differentiable utility index that depends on consumption, c_t, and leisure, l_t. The time endowment is normalized to 1, hence labor effort is $h_t = 1 - l_t$. The utility maximization problem is subject to a flow budget constraint,

$$c_t + d_{t+1} + T_t \leq (1-\tau_t)w_t h_t + R_t d_t + [\pi_t^f + \pi_t^b]; \qquad t \geq 0 \tag{2.2}$$

that restricts the household's expenditure to not exceed its income at any time. The sources of income are net labor income, gross return on deposits, and dividends. Net labor income

المنارة للاستشارات
www.manaraa.com

depends on the wage rate, w_t, the amount of labor supplied, h_t, and the tax rate on labor income, τ_t. Bank deposits, d_t, are the only savings vehicle available to the household and they are remunerated at the gross rate R_t. Furthermore, as the household owns all firms and banks in the economy, it collects the respective profits, π_t^f and π_t^b. The household allocates its resources between savings, d_{t+1}, i.e., deposits payable next period, consumption, c_t, and the payment of the lump-sum tax, T_t.

A sequence $\{c_t, h_t, d_{t+1}\}_{t=0}^{\infty}$ is optimal from the household's standpoint if it satisfies the resource constraint in Eq. (2.2) with equality and if the following conditions hold at $t \geq 0$:

$$\frac{U_l(t)}{U_c(t)} = (1 - \tau_t)w_t \tag{2.3}$$

$$U_c(t) = \beta U_c(t+1)R_{t+1} \tag{2.4}$$

where $U_c(t)$ and $U_l(t)$ are the marginal utilities of consumption and leisure at time t. Eq. (2.3) equates the marginal rate of substitution of leisure for consumption to the wage rate net of taxes, and Eq. (2.4) is a standard dynamic efficiency condition for savings that governs the optimal allocation of deposits. The tax on labor income lowers the net wage received by the households, which reduces the consumption-leisure ratio. Thus the substitution effect of a labor tax results in a fall in consumption and labor effort.

2.2.2 Firms and the Working Capital Constraint

The representative firm owns a fixed capital stock, $\bar{k}$, which is combined with labor, h_t, to produce the final good, y_t, using a constant returns to scale production function:

$$y_t = f(\bar{k}, h_t) \tag{2.5}$$

The firm faces a working capital constraint on its wage bill: it has to borrow from banks to finance its labor costs before cashing its sales. Hence firms borrow b_t $(= w_t h_t)$ from the banks. Due to rents accruing to the fixed capital stock, the firm makes positive profits that are distributed to the households. The firm chooses h_t to maximize its profits, $\pi_t^f = y_t - R_{bt} w_t h_t$, taking as given the wage rate, w_t, and the gross interest rate on its borrowing, R_{bt}. Optimality

www.manaraa.com

requires that:

$$R_{bt}w_t = f_h(\bar{k}, h_t) \tag{2.6}$$

and linear homogeneity of the production function allows us to write the firm's profit as:

$$\pi_t^f = \bar{k} f_k(\bar{k}, h_t) \tag{2.7}$$

which is the return to the stock of physical capital.

2.2.3 Banks and Banking Crises

Following Cole and Ohanian (2000), we model the representative bank as follows. The bank accepts one-period deposits, d_t, from households and uses them along with banking capital to produce loans, b_t, using a Leontief production function:

$$b_t = \min(\gamma A_t, d_t); \qquad \gamma \in (0, \infty) \tag{2.8}$$

where A_t is the banking capital stock that is owned by the bank and it is in fixed supply ($\bar{A}$) in the pre-crisis equilibrium. The bank chooses d_t to maximize its profits, $\pi_t^b = (R_{bt} - 1)b_t - (R_t - 1)d_t$, taking as given the lending rate, R_{bt}, and the deposit rate, R_t. The bank's maximization problem leads to the following optimality condition:

$$b_t = d_t = \gamma A_t \tag{2.9}$$

which equates the volume of loans to that of deposits and to γ times the banking capital stock.

We model a banking crisis by assuming an unanticipated exogenous decrease in the stock of banking capital. This is in keeping with the banking crises documented in Chava and Purnanandam (2006) and the definitions of Caprio and Klingebiel (2003). If a crisis occurs in period t^c, the stock of banking capital declines from $A_t = \bar{A}$ during the non-crisis times (i.e., $\forall t < t^c$), to $A_{t^c} = \underline{A}$ at the crisis time. It can then be seen from Eq. (2.9) that a crisis that erodes a portion of the banking capital stock results in a decline in the supply of loans. We do not model why nor how the crisis happens[2]; instead, we take the crisis as given and carry out our analysis from period t^c on to consider the optimal path of banking capital injections.

[2] See Demiirgüç-Kunt and Detragiache (1998) for a discussion of the causes of banking crises.

المنارة للاستشارات
www.manaraa.com

2.2.4 Government

Regardless of the existence of a crisis or of an ongoing bank recapitalization program, we assume that the government has a constant level of unproductive expenditures, $\bar{g}$, which it finances by resorting to lump-sum taxes. This assumption pursues a two-fold goal: it permits matching the normal level of government expenditures to output ratio in developing countries while isolating the effects of financing a bank recapitalization program from that of financing normal government expenditures.

Following what has been observed in countries that have faced banking crises, we assume that the government gets drawn into restructuring the banking sector, although this is shown to be optimal in the model above when the private sector is ruled out from recapitalizing the banks. When a crisis triggers the implementation of a bank recapitalization program, in addition to $\bar{g}$, the government has to spend x_t to inject capital to the banking system. Capital injections make the banking capital stock evolve according to $A_{t+1} = A_t + x_t$. We characterize the optimal path of x_t under alternative sources of financing the recapitalization program. The general form of the government budget constraint is:

$$\bar{g} + x_t + R^* b_t^g = \tau_t w_t h_t + b_{t+1}^g + T_t \tag{2.10}$$

where b_t^g is the time t stock of international debt issued by the government and R^* is the gross interest rate on international debt. We will later specialize this constraint according to the funding sources available to the government.

2.2.5 Competitive Equilibrium

A competitive equilibrium is a sequence of allocations, $\{c_t, h_t, d_{t+1}, A_{t+1}\}_{t=0}^{\infty}$; a sequence of prices, $\{w_t\}_{t=0}^{\infty}$; a sequence of interest rates, $\{R_t, R_{bt}\}_{t=0}^{\infty}$; and a sequence of government policies, $\{x_t,\ \tau_t, T_t, b_{t+1}^g\}_{t=0}^{\infty}$, such that: a) households solve their constrained lifetime utility-maximization problem, i.e., Eq.s (2.2) - (2.4) hold; b) firms maximize their profits, i.e., Eq. (2.6) and the working capital constraint on the firm hold with equality; c) banks maximize their profits, i.e., Eq. (2.9) holds; d) the government budget constraint is satisfied; and e) the labor, output, deposit, and loan markets clear.

www.manaraa.com

2.3 Optimal Bank Recapitalization Programs: A Ramsey Approach

To characterize Ramsey-optimal bank recapitalization programs, in this section, we formulate the Ramsey problems corresponding to each of three sources of recapitalization financing: i) the recapitalization is undertaken using revenue from labor-income taxes, ii) lump-sum taxes finance the recapitalization, and iii) the government borrows in international debt markets to recapitalize the banking sector and only distortionary taxes are available to repay the contracted debt.

2.3.1 Labor Income Taxation

Consider the Ramsey planner's problem when the government has to resort to taxation of labor income to finance the recapitalization of the banking system. Here, $\forall t$, $T_t = \bar{g}$ and $b_t^g = 0$, so the government budget constraint, Eq. (2.10), becomes:

$$x_t = A_{t+1} - A_t = \tau_t w_t h_t \tag{2.11}$$

The implementability constraint for the Ramsey planner is derived by substituting the household's, firm's and bank's optimality conditions along with the expressions for the profits of firms and banks into the household budget constraint:

$$U_c(t)[c_t + \gamma A_{t+1} + \bar{g} - f(\bar{k}, h_t)] = U_l(t)h_t \tag{2.12}$$

The resource constraint for the economy is derived by combining the household and the government budget constraints:

$$c_t + \bar{g} + (1+\gamma)A_{t+1} = (1+\gamma)A_t + f(\bar{k}, h_t) \tag{2.13}$$

The Ramsey planner's problem is

$$\max_{\{c_t, h_t, A_{t+1}\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \beta^t U(c_t, l_t) \qquad \text{s.t. } (2.12), \text{ and } (2.13)$$

Let $\beta^t \mu_t$ be the multiplier on the implementability constraint and $\beta^t \nu_t$ be the multiplier on the resource constraint. Assuming $U_{lc}(.) = U_{cl}(.) = 0$, the optimality conditions are the

المنارة للاستشارات
www.manaraa.com

implementability and resource constraints, Eq.s (2.12) and (2.13), along with the following:

$$U_c(t) = \mu_t[U_c(t) + U_{cc}(t)\{c_t + \gamma A_{t+1} + \bar{g} - f(\bar{k}, h_t)\}] + \nu_t \tag{2.14}$$

$$U_l(t) = \mu_t[U_l(t) - U_{ll}(t)h_t + U_c(t)f_h(\bar{k}, h_t)] + \nu_t f_h(\bar{k}, h_t) \tag{2.15}$$

$$\mu_t U_c(t)\gamma + \nu_t(1+\gamma) = \beta\nu_{t+1}(1+\gamma) \tag{2.16}$$

where Eq.s (2.14), (2.15), and (2.16) are the first order conditions with respect to c_t, h_t, and A_{t+1}, respectively.

It is worth emphasizing that the above Ramsey planner's problem is different from the standard version of the Ramsey problem where the government has to fund a stream of unproductive government expenditures. In our case the government needs to raise resources to recapitalize the banking system, and given that banking capital is an essential input in the loan production function, the government needs to finance a productive expenditure[3]. At designing the optimal recapitalization path, the planner needs to balance the benefit of recapitalizing the banking system with the costs of raising the resources to do so. On the cost side, apart from withdrawing resources from consumption, the tax on labor income distorts the consumption-leisure choice. The benefit of recapitalizing the banks is a better capitalized banking system that is able to extend more loans at a lower interest rate to the firms, which in turn leads to economywide increases in employment, output, and consumption.

2.3.2 Lump-sum Taxes

When the planner has access to lump-sum taxes to finance the recapitalization program but the economy is excluded from international debt markets, $b_t^g = \tau_t = 0$; in this case, the government budget constraint can be written as:

$$\bar{g} + A_{t+1} - A_t = T_t \tag{2.17}$$

[3]Recent papers that consider Ramsey planner's problems with productive public expenditure include Riascos and Végh (2004), and Klein et al. (2007) where government expenditure provides utility to consumers, while Azzimonti et al. (2006) focus on time consistency issues when public capital is an input in private production.

www.manaraa.com

where it is understood that absent any recapitalization program, $T_t = \bar{g}$. The household budget constraint, Eq. (2.2), is now

$$c_t + d_{t+1} + T_t \leq w_t h_t + R_t d_t + [\pi_t^f + \pi_t^b]; \qquad t \geq 0 \tag{2.18}$$

In a standard Ramsey problem, when the planner has access to lump-sum taxes, and there are no other distortions in the economy, the solution involves maximizing the household's objective function subject to the economywide resource constraint. In our case, however, the working capital constraint acts as another distortion in the economy that requires imposing the following implementability constraint on the Ramsey planner's problem:

$$U_c(t)[c_t + (1+\gamma)A_{t+1} + \bar{g} - f(\bar{k}, h_t) - A_t] = U_l(t)h_t \tag{2.19}$$

This constraint arises from substituting into the household's budget constraint, Eq. (2.18), the profit functions for the firms and banks, the household and bank optimality conditions, and the value of the government capital injections. The resource constraint for the economy is the same as before, and is repeated here for convenience:

$$c_t + \bar{g} + (1+\gamma)A_{t+1} = (1+\gamma)A_t + f(\bar{k}, h_t) \tag{2.20}$$

The Ramsey planner's problem is

$$\max_{\{c_t, h_t, A_{t+1}\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \beta^t U(c_t, l_t) \qquad \text{s.t. } (2.19), \text{ and } (2.20)$$

Let $\beta^t \mu_t$ and $\beta^t \nu_t$ be the multipliers on the implementability constraint and the resource constraint, respectively . Under the assumption that $U_{lc}(.) = U_{cl}(.) = 0$, optimality requires satisfying the implementability and the resource constraints, Eq.s (2.19) and (2.20), as well as the following conditions:

$$U_c(t) = \mu_t[U_c(t) + U_{cc}(t)\{c_t + (1+\gamma)A_{t+1} + \bar{g} - f(\bar{k}, h_t) - A_t\}] + \nu_t \tag{2.21}$$

$$U_l(t) = \mu_t[U_l(t) - U_{ll}(t)h_t + U_c(t)f_h(\bar{k}, h_t)] + \nu_t f_h(\bar{k}, h_t) \tag{2.22}$$

$$\mu_t U_c(t)(1+\gamma) + \nu_t(1+\gamma) = \beta\mu_{t+1}U_c(t+1) + \beta\nu_{t+1}(1+\gamma) \tag{2.23}$$

المنارة للاستشارات
www.manaraa.com

where Eq.s (2.21), (2.22), and (2.23) are the first order conditions with respect to c_t, h_t, and A_{t+1}, respectively.

Although the taxes are non-distortionary, the recapitalization program involves withdrawing resources that, otherwise, would be allocated to consumption. The planner needs to balance the cost of the current reduction in consumption with the current and future benefits of a better capitalized banking system and this characterizes the optimal recapitalization path.

2.3.3 Government Access to International Debt

When the government has access to international debt and lump-sum taxes are available only to fund the constant level of government expenditures, $\bar{g}$, the resource constraint for the economy is the following:

$$c_t + \bar{g} + (1+\gamma)A_{t+1} + R^* b_t^g = (1+\gamma)A_t + f(\bar{k}, h_t) + b_{t+1}^g \tag{2.24}$$

The implementability constraint in this case is:

$$U_c(t)[c_t + \gamma A_{t+1} + \bar{g} - f(\bar{k}, h_t)] = U_l(t) h_t \tag{2.25}$$

Thus, the Ramsey planner's problem, when the government has access to international debt, is

$$\max_{\{c_t, h_t, A_{t+1}, b_{t+1}^g\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \beta^t U(c_t, l_t) \qquad \text{s.t. } (2.24), \text{ and } (2.25)$$

As before, let $\beta^t \mu_t$ be the multiplier on the implementability constraint and $\beta^t \nu_t$ be the multiplier on the resource constraint, and assume that $U_{lc}(.) = U_{cl}(.) = 0$. Optimality now requires satisfying the constraints (2.24) and (2.25) and the following conditions:

$$U_c(t) = \mu_t[U_c(t) + U_{cc}(t)\{c_t + \gamma A_{t+1} + \bar{g} - f(\bar{k}, h_t)\}] + \nu_t \tag{2.26}$$

$$U_l(t) = \mu_t[U_l(t) - U_{ll}(t) h_t + U_c(t) f_h(\bar{k}, h_t)] + \nu_t f_h(\bar{k}, h_t) \tag{2.27}$$

$$\mu_t U_c(t)\gamma + \nu_t(1+\gamma) = \beta \nu_{t+1}(1+\gamma) \tag{2.28}$$

$$\nu_t = \beta \nu_{t+1} R^* \tag{2.29}$$

المنارة للاستشارات
www.manaraa.com

where Eq.s (2.26), (2.27) (2.28), and (2.29) are the first order conditions with respect to c_t, h_t A_{t+1}, and b^g_{t+1}, respectively.

When the planner weighs the benefits and costs of the banks' recapitalization program, he knows that by borrowing from international debt markets, he can secure the funds necessary to recapitalize the banks, and thereby overcome the need of withdrawing all the required resources from consumption. The cost of this strategy is, however, that in the future, the repayment of the debt incurred to recapitalize the banks will require resorting to distortionary labor-income taxes.

2.4 Quantitative Results

In this section we analyze the quantitative implications of a banking crisis, provide the post-crisis transition paths and discuss the welfare effects of government intervention in each of the three considered sources of resources to recapitalize the banks.

2.4.1 Functional Forms and Parameters

To solve the model numerically we assume the following functional forms. The utility function is separable in consumption and leisure:

$$U(c_t, l_t) = \ln c_t + \theta \ln l_t$$

and the production function is Cobb Douglas:

$$y_t = B\bar{k}^{\alpha} h_t^{1-\alpha}, \qquad \alpha \in (0,1)$$

The baseline parameter values, which are shown in Table 2.1, are chosen to be representative of the main macroeconomic and banking conditions in developing countries. The annual net rate of interest on international debt is set at 5%. The household discount factor is set equal to $1/R^*$, which gives $\beta = 0.9879$. The parameter, θ, that determines the share of leisure in the household utility function, is set to 1.5, so that work effort is approximately 1/3 of the total time endowment. Following the standard in the literature, the share of physical capital in production of the final good, α, is set at 1/3. The capital stock, $\bar{k}$, and the productivity

المنارة للاستشارات
www.manaraa.com

parameter, B, are set such that the capital-output ratio, on annual basis, is about 2. The banking capital to deposit ratio in the loan production function is set at 1/10, i.e., $\gamma = 10$, although we later compare the welfare effects for different values of γ. The fixed component of government outlays, $\bar{g}$, is set equal to 2, so that the steady-state government consumption is equal to about 14% of output, as reported by the United Nations for developing countries[4]. The initial steady state level of banking capital, $\bar{A}$, is calibrated to match an annual net interest rate on loans of 8.5%, which generates $\bar{A} = 0.9222$. One period in the model is interpreted as one quarter.

2.4.2 Transition Dynamics

The timing of events is as follows: at the beginning of period 0 the economy is in steady state and at the end of that period the economy is hit by a banking crisis, hence $t^c = 0^+$; in this same time period, the government initiates its optimal bank recapitalization program. In the empirical literature, a banking crisis is defined as much or all of the banking capital being exhausted (see for instance Caprio and Klingebiel (2003)). Taking an approximate mid-point, we discuss the results for a 50% decline in banking capital under the three financing methods.

Figure 2.1 plots the transitional dynamics induced by the banking crisis and the subsequent government intervention for the three sources of financing discussed above. Given the Leontief structure of the bank-loan production technology, deposits and bank loans follow the same path as banking capital. Also, given the fixed physical capital stock, the path of employment and output are similar.

Consider first the case where the recapitalization is financed by labor-income taxes. In the first period, which is the period of unraveling of the banking crisis, the low stock of bank capital constrains the credit that banks can extend to the firms, which in turn reduces employment and output. Recapitalizing the banks requires a high tax on labor income, which decreases labor supply via the substitution effect, adding another negative effect on labor and output. All in all, consumption declines. The maximum amount of banking capital injections occurs

[4] See, for example, the United Nations Online Network in Public Administration and Finance data on government consumption as a percentage of GDP in developing countries.

www.manaraa.com

during the first period because the marginal benefit of increasing the stock of banking capital is at its highest level. As the stock of banking capital increases, the marginal benefit of further injections declines. From the second period onward, as the amount of injections decline, so does the tax rate on labor income. Due to the increasing banking capital stock, and hence bank loans, firms are able to borrow and produce more, so the economy starts recovering from the recession caused by the banking crisis. Owing to the high resource cost and the distortionary nature of financing the recapitalization program, the optimal recapitalization path is a gradual one.

Consider now the case where lump-sum taxes are available; this is equivalent to the government issuing domestic bonds to pay for the recapitalization program and having access to taxes on the rents accruing to the stocks of capital. On impact, employment, consumption and output decline as the economy responds to the high interest rate on working-capital loans. Since the resources for recapitalization are raised using non-distortionary methods, employment, and hence output, fall less than in the case of distortionary taxes. Although the method of taxation is non-distortionary, consumption smoothing entails a gradual recapitalization path due to the large amount of resources involved. Again, the amount of injections decline over time due to the declining marginal benefit of these injections as the stock of banking capital increases.

When the government has access to international lending, even if the only taxes available are distortionary, the optimal recapitalization is undertaken in one shot and, at the same time, the government is able to smooth consumption completely by borrowing from abroad. Banking capital, and hence bank loans, reach their new steady state level in period 2, while consumption and employment (hence output) adjust to their new steady state levels in period 1 itself. Although the banking capital stock, and hence the amount of bank loans, is low and the firms are working-capital constrained, the government borrows from international debt markets to subsidize employment in period 1. Due to this, households are willing to supply labor to the firms even at a low gross wage rate, w_t. Hence, even with a low banking capital stock in period 1, due to the subsidy to labor income, consumption, employment and output

المنارة للاستشارات
www.manaraa.com

are at their new steady-state levels.

Table 2.2 reports the steady state levels of banking capital, output and consumption. Given the real resource cost of increasing the stock of banking capital, optimality dictates that the marginal cost of financing the bank recapitalization be equated to the marginal benefit of an extra unit of banking capital. When labor-income taxes finance the recapitalization program, apart from having large resource costs, these taxes further distort the economy. With access to lump-sum taxes, the government is able to avoid the distortions caused by the labor-income taxes, but the resources for recapitalization still need to be financed domestically. Only when borrowing from international debt markets is allowed, can the government completely spread out the recapitalization costs over time. Hence, the steady state levels of banking capital, deposits, loans, employment and output are the highest when there is access to international debt markets, followed by the case of non-distortionary taxes. However, steady state consumption is the lowest with access to international debt, in spite of employment and output being the highest: this is because part of the output is used to pay interest on the country's debt obligations, which in turn requires the households to work more.

2.4.3 Welfare Effects

We compute a number of measures of the welfare effects of a banking crisis (for the different sources of financing) to highlight different aspects of the welfare costs of a crisis. In all cases the no-crisis equilibrium is the benchmark. First, following Lucas (1987), we define the net welfare effects of a banking crisis, λ_1, as the permanent, constant decrease in the no-crisis steady state consumption, $\bar{c}$, for $t = 0, 1, \ldots, \infty$, that leaves households indifferent between the lifetime utility obtained in the no-crisis equilibrium and lifetime utility under the crisis equilibria, inclusive of the transitional dynamics of consumption, c_t, and leisure, l_t:

$$\sum_{t=1}^{\infty} \beta^{t-1} \left[\ln\{(1-\lambda_1)\bar{c}\} + \theta \ln \bar{l}\right] = \sum_{t=1}^{\infty} \beta^{t-1} \left[\ln c_t + \theta \ln l_t\right] \tag{2.30}$$

where $\bar{l}$ is the no-crisis steady state leisure.

While the post-crisis consumption is lower than the no-crisis consumption, the post-crisis employment is always lower than the pre-crisis level. In computing welfare, this drop in

www.manaraa.com

employment (increase in leisure) compensates, to some extent, for the lower consumption. To highlight the effect of lower consumption alone, on welfare, we also compute the above welfare effects holding leisure fixed at the pre-crisis steady state level. Thus we define the welfare measure, λ_2, as:

$$\sum_{t=1}^{\infty} \beta^{t-1} \left[\ln\{(1-\lambda_2)\bar{c}\} + \theta \ln \bar{l}\right] = \sum_{t=1}^{\infty} \beta^{t-1} \left[\ln c_t + \theta \ln \bar{l}\right] \tag{2.31}$$

In all cases, the welfare loss computed using our second measure is higher than the one using the first measure because in both methods the consumption profile is the same, given the financing method, but in the second measure employment (leisure) is higher (lower), which reduces the crisis utility level.

To highlight the fact that the transitional costs of a bank recapitalization program, due to decline in consumption, are more severe than the lifetime cost of the crisis, we compute the welfare loss arising purely from the transitional dynamics of the movement to the post-crisis steady state, under different programs. Note that the times of convergence to the new steady states, t^{ss}, are different for the different financing methods, reflecting the difference in distortions under different recapitalization programs. We characterize welfare loss as the equivalent permanent reduction in the no-crisis steady state consumption, defining λ_3 such that:

$$\sum_{t=1}^{t^{ss}} \beta^{t-1} \left[\ln\{(1-\lambda_3)\bar{c}\} + \theta \ln \bar{l}\right] = \sum_{t=1}^{t^{ss}} \beta^{t-1} \left[\ln c_t + \theta \ln l_t\right] \tag{2.32}$$

Finally, to characterize the effect of lower consumption alone on welfare, in computing the welfare loss induced by the transitional dynamics of a bank restructuring program, we hold leisure fixed at the no-crisis steady state level, and define λ_4 to satisfy:

$$\sum_{t=1}^{t^{ss}} \beta^{t-1} \left[\ln\{(1-\lambda_4)\bar{c}\} + \theta \ln \bar{l}\right] = \sum_{t=1}^{t^{ss}} \beta^{t-1} \left[\ln c_t + \theta \ln \bar{l}\right] \tag{2.33}$$

The results for the welfare comparisons are presented in Table 2.3. We discuss these results for our baseline calibration of a banking capital to deposit ratio of 1/10, i.e., $\gamma = 10$, and we use other values of γ for sensitivity analysis. If the government does not recapitalize the banking system in the aftermath of a crisis and the banking capital stock stays at the crisis level infinitely, then the welfare loss is a decline of 5.51% in the no-crisis steady state consumption

المنارة للاستشارات
www.manaraa.com

using our first measure and 22.08% using the second measure. Recall that the reason for the higher value of welfare loss using the second measure is that, while consumption is at the crisis level, we hold employment (leisure) fixed at the high (low) no-crisis level.

The net welfare loss of a crisis with recapitalization financed by distortionary taxes are 0.65% and 1.42% of the no-crisis consumption using the first and second measures, respectively. The welfare loss purely due to the transitional dynamics involved in the movement to the new steady state is 2.69% of the no-crisis consumption, and is higher at 4.46% if employment (leisure) is held constant at the no-crisis level.

Financing the recapitalization with non-distortionary taxes results in a welfare loss of 0.63% (1.35%) of the no-crisis consumption using our first (second) measure. The welfare loss is to the order of 2.74% due to the transitional dynamics alone, and it is 4.35% if we also hold employment fixed at the no-crisis level.

Access to international debt eases the welfare cost of a banking crisis considerably, and the welfare loss of a banking crisis is 0.51% of steady state consumption using our first and third measures, while it is 0.72% using the second and fourth measures. The lifetime and transition measures coincide in the case of international debt access because the government, by borrowing from international markets, is able to achieve intertemporal smoothing, and consumption and employment jump to the new steady state values in period 1 itself, while banking capital reaches the new steady state in period 2.

Apart from the welfare effects in the benchmark case, we also compute the above welfare measures for other values of the banking capital to deposit ratio. As shown in Table 2.3, the welfare losses due to a banking crisis, given the method of financing of the recapitalization program, is increasing (decreasing) in the banking capital-deposit ratio (γ). Figure 2.2 plots the welfare costs of banking crises, using measure 1, for different values of γ. As γ increases, i.e., as the banking capital to deposit ratio in the economy declines, the pre-crisis steady state banking capital stock declines. This is because, given the other parameters, the amount of banking capital required to produce the same amount of loans declines. Hence, the welfare loss due to a crisis, given the recapitalization program, declines because the amount of resources

المنارة للاستشارات
www.manaraa.com

required for the recapitalization program decreases with the decline in the initial loss of banking capital.

2.5 Concluding Remarks

Banking sector crises, which have been prevalent in both developing and developed countries, have presented a stiff challenge to policy makers. Given the public-good aspect of a well running financial system, governments almost invariably end up bearing the burden of financing the restructuring programs necessary to recapitalize a bankrupt banking system. The high fiscal cost of these programs warrants careful analysis of the financing options used by the government.

In this chapter we undertook a first attempt at examining the public-finance aspect of the government's recapitalization of a bankrupt banking sector in a dynamic general equilibrium setting. We formulate the Ramsey planner's problems under three different scenarios: recapitalizations financed with distortionary taxes, with non-distortionary taxes and by borrowing from international debt markets. The Ramsey problems were solved numerically and the welfare costs of a banking crisis were found to be substantial.

The post restructuring levels of banking capital are different under the three regimes, reflecting the difference in distortions due to the different financing options of the recapitalization program. It has often been suggested that the government should restructure the banking system in one shot, but our analysis of the Ramsey planner's problems shows that optimality requires a gradual approach unless the economy can borrow from international markets. This is because the high resource cost typically involved in a restructuring program should be spread out over time to minimize the distortions introduced in funding the program. This highlights the importance of having access to international debt markets during period of financial distress; furthermore, the results discussed here may also justify why under some circumstances it might be highly convenient to have international organizations extending emergency financing to developing countries hit by banking crises. This financing could alleviate the effects of a banking crisis and avoid a rather painful and long-drawn adjustment process in the post-crisis

المنارة للاستشارات
www.manaraa.com

scenario.

We have not considered the moral hazard problems arising from the government intervention in financial markets, nor have we incorporated the different methods used for recapitalization[5], which can have different effects on the government budget. These issues are important and present avenues for future research. Another possible avenue for future research is the explicit modeling of why private agents do not accumulate banking capital, which necessitates government intervention.

[5] For details on the latter, see Daniel et al. (1997).

www.manaraa.com

Table 2.1: Baseline parameter values

	Parameters	Values
β	Discount factor	0.988
θ	Leisure share parameter in utility	1.5
B	Productivity parameter	6
$\bar{k}$	Physical capital stock	115
α	Capital's share in output	1/3
γ	Ratio of deposits to banking capital	10
$\bar{g}$	Fixed government consumption	2
R^*	Quarterly world interest rate	1.012

Table 2.2: Steady state values under baseline parameters

Variable	**Pre-crisis**	**Post-crisis**			
		No intervention	Labor tax	Lump-sum Tax	International Debt
A	0.922	0.461	0.910	0.910	0.918
y	14.118	11.443	14.062	14.063	14.091
c	12.118	9.443	12.062	12.063	12.030
h	0.337	0.246	0.335	0.335	0.336

Notes: The steady state levels of the variables are different for the different programs reflecting the difference in distortions due to the different financing options of the recapitalization programs. For the time period in which the economy converges to the new steady state, under different financing methods, see Table 2.3.

www.manaraa.com

Table 2.3: Welfare effects of banking crises

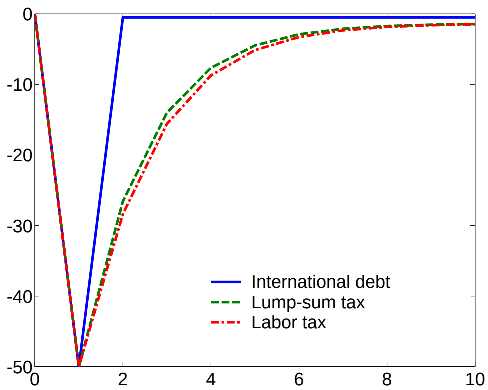
(50% decline in banking capital)

γ	1	5	**10**	15	20
Period of convergence to new steady state (t^{ss})					
Labor Tax	44	27	**23**	23	22
Lump-sum Tax	34	25	**22**	21	22
International Debt	2	2	**2**	2	2
Welfare Effects: λ_i (in percentages)					
$\lambda_1 \ni \sum_{t=1}^{\infty} \beta^{t-1} \left[\ln\{(1-\lambda_1)\bar{c}\} + \theta \ln \bar{l}\right] = \sum_{t=1}^{\infty} \beta^{t-1} \left[\ln c_t + \theta \ln l_t\right]$					
No Intervention	5.51	5.51	**5.51**	5.51	5.51
Labor Tax	1.19	0.71	**0.65**	0.63	0.62
Lump-sum Tax	1.07	0.68	**0.63**	0.62	0.61
International Debt	0.91	0.55	**0.51**	0.49	0.49
$\lambda_2 \ni \sum_{t=1}^{\infty} \beta^{t-1} \left[\ln\{(1-\lambda_2)\bar{c}\} + \theta \ln \bar{l}\right] = \sum_{t=1}^{\infty} \beta^{t-1} \left[\ln c_t + \theta \ln \bar{l}\right]$					
No Intervention	22.08	22.08	**22.08**	22.08	22.08
Labor Tax	3.46	1.65	**1.42**	1.37	1.30
Lump-sum Tax	2.87	1.53	**1.35**	1.34	1.26
International Debt	2.06	0.88	**0.72**	0.67	0.65
$\lambda_3 \ni \sum_{t=1}^{t^{ss}} \beta^{t-1} \left[\ln\{(1-\lambda_3)\bar{c}\} + \theta \ln \bar{l}\right] = \sum_{t=1}^{t^{ss}} \beta^{t-1} \left[\ln c_t + \theta \ln l_t\right]$					
Labor Tax	2.81	2.55	**2.69**	2.61	2.66
Lump-sum Tax	3.08	2.63	**2.74**	2.79	2.64
International Debt	0.91	0.55	**0.51**	0.49	0.49
$\lambda_4 \ni \sum_{t=1}^{t^{ss}} \beta^{t-1} \left[\ln\{(1-\lambda_4)\bar{c}\} + \theta \ln \bar{l}\right] = \sum_{t=1}^{t^{ss}} \beta^{t-1} \left[\ln c_t + \theta \ln \bar{l}\right]$					
Labor Tax	6.10	4.46	**4.46**	4.41	4.32
Lump-sum Tax	5.43	4.25	**4.35**	4.61	4.18
International Debt	2.06	0.88	**0.72**	0.67	0.65

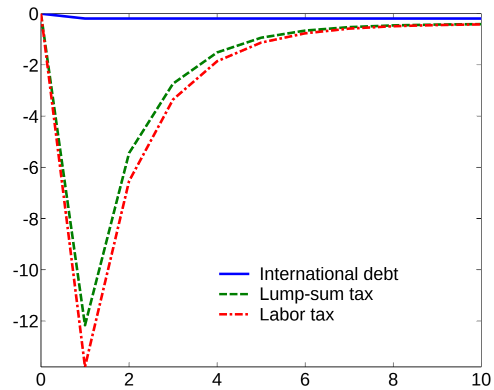
Notes: The no-crisis case is the benchmark for these welfare comparisons. γ is the deposit to banking capital ratio in the economy; $\bar{c}$ and $\bar{l}$ are the no-crisis steady state consumption and leisure levels; c_t and l_t are consumption and leisure in the crisis equilibrium. The measures of the welfare loss of a banking crisis are defined as the permanent, constant percentage declines in the no-crisis steady state consumption that leave households indifferent between the no-crisis equilibrium and the crisis equilibria, i.e., the λ_i's satisfy the respective equations.

المنارة للاستشارات

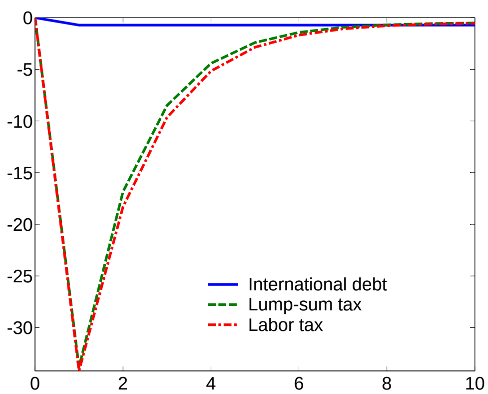
www.manaraa.com



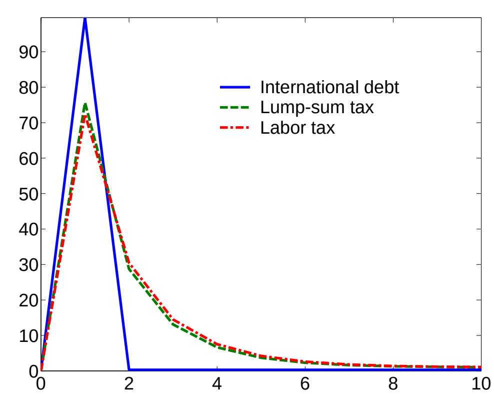
(a) Banking Capital



(b) Output



(c) Consumption



(d) Interest rate on loans

Figure 2.1: Dynamics in the aftermath of a banking crisis under the three recapitalization programs.

Notes: A banking crisis, that erodes 50% of the banking capital stock, occurs in period 0; from period 1, the government initiates its optimal recapitalization program. All values in the above graphs are % deviations from the pre-crisis steady state.

المنارة للاستشارات
www.manaraa.com

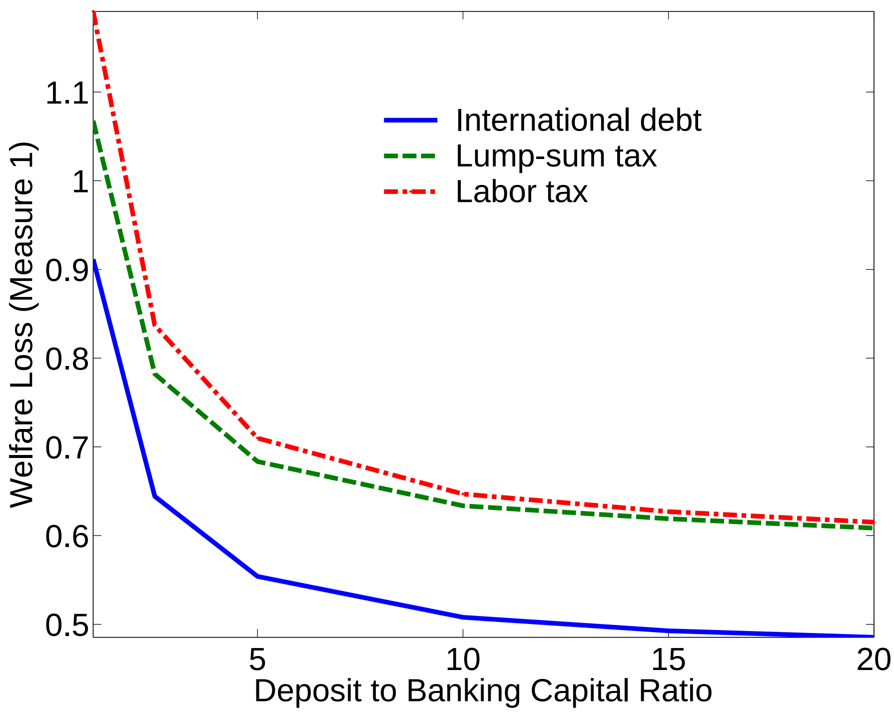


Figure 2.2: Welfare costs of banking crises.

Notes: The no-crisis equilibrium is the benchmark for these welfare costs. All values in the graph are for welfare measure 1 where λ_1 is the permanent, constant percentage decrease in the no-crisis steady state consumption, $\bar{c}$, given the no-crisis leisure $(\bar{l})$, for $t = 0, 1, \ldots, \infty$, that leaves households indifferent between the lifetime utility obtained in the no-crisis equilibrium and lifetime utility under the crisis equilibria, inclusive of the transitional dynamics of consumption, c_t, and leisure, l_t, i.e., $\sum_{t=1}^{\infty} \beta^{t-1} \left[\ln\{(1-\lambda_1)\bar{c}\} + \theta \ln \bar{l}\right] = \sum_{t=1}^{\infty} \beta^{t-1} \left[\ln c_t + \theta \ln l_t\right]$.

المنارة للاستشارات
www.manaraa.com

CHAPTER 3. STRATEGIC ENVIRONMENTAL POLICY UNDER FREE TRADE WITH TRANSBOUNDARY POLLUTION

(This chapter is a close version of Sikdar and Lapan (2007).)

3.1 Introduction

A serious concern about the relationship between trade and environmental policy is that these two issues have usually been dealt with separately in real-world bilateral or multilateral agreements. When trade agreements forbid the use of trade policies to pursue terms of trade goals, governments may use domestic environmental policies as a second best method of pursuing their terms of trade objectives. Other reasons that might motivate the distortion of domestic environmental policies are the competition to attract more industries (capital) from countries with stricter policies and to capture rents from foreign firms in the presence of imperfect competition. While prior research has shown that when there are no transboundary externalities negotiating tariffs, in conjunction with commitments to market access, can lead to efficiency (see, for example, Bagwell and Staiger (2001)), efficiency will not result from trade agreements alone when there are transboundary externalities. In this chapter we explore the effects of trade liberalization on environmental outcomes and welfare, in the presence of transboundary pollution, when environmental policy is set non-cooperatively.

The literature on trade and environmental policy in the presence of an international spillover of emissions is too vast to be adequately surveyed here. Some papers assume the pollution externality affects firm productivity, whereas other papers assume the externality hurts households (an "eyesore" externality). Papers also differ in terms of the policy tools allowed (domestic policies, border policies, or both), the number of policy active countries, and in terms of country size. Since we investigate how, in the presence of an eyesore transboundary externality,

www.manaraa.com

the movement from autarky to free trade affects domestic policy and welfare, our literature review focuses on papers with similar structures.

Markusen (1975), one of the first papers to address transboundary pollution, considers one policy active country that uses both tariffs and domestic policy to influence the terms of trade and global pollution output. Rauscher (1997) derives the optimal environmental tax under free trade for a large country that suffers from transboundary pollution. He finds that "carbon leakage" occurs if stricter domestic environmental policy leads to increases in foreign emissions and concludes that with "substantial leakage effects, optimal environmental policies tend to lead to too low emission tax rates" when the pure terms of trade effects are small compared to leakage effects. However, he considers the case in which only one country is policy active. Copeland (1996) considers a small country (A) which suffers transboundary pollution from production of its import good in a neighboring economy (B). Since both countries are small and there are transportation costs between the ROW and these two countries, import tariffs in A will not affect production in B, provided B exports to ROW. However, an import tariff on pollution content can change the way in which B produces output, and hence can reduce the amount of transboundary pollution[1].

Ludema and Wooton (1994) consider strategic policy in a two country asymmetric trade model with transboundary pollution. Foreign production, which is exported to the home country, generates eyesore pollution that affects only the home country. Under a free trade agreement the foreign country, which is not affected by the pollution, implements environmental policies to manipulate its terms of trade, while the home country uses process standards[2] to improve its terms of trade and restrict the incidence of transboundary pollution.

Copeland and Taylor (1995) study a Heckscher-Ohlin two factor model in which eyesore pollution is one of two primary inputs. Assuming pollution is a pure global public good and that there is free trade, they evaluate the welfare implications of trade when countries non-cooperatively choose their environmental policy, pollution permits. They find that, as

[1] If foreign output and pollution were in a one-to-one correspondence, then the tariff on imports and tariff on pollution content would be identical.

[2] As the authors themselves note, such standards would be in violation of WTO rules, so we are not sure if such policies would be viable under free trade.

www.manaraa.com

compared to autarky, emissions in the South rise and emissions in the North fall; aggregate world pollution rises if trade does not lead to factor price equalization (FPE), while under FPE aggregate world pollution is unaffected by trade. Allowing free trade in pollution permits across countries guarantees FPE and hence eliminates the possibility that global emissions increase. While most of the paper assumes countries ignore the effect of their policies on world prices[3], even when countries take into account this effect, the equilibrium coincides with the earlier case because of the pure global public good nature of pollution. We derive a similar result in our model, as a special case, in Section 3.5.3.

Kiyono and Okuno-Fujiwara (2003) consider strategic interactions between two closed economies with respect to environmental policies. Emissions (a by-product of production) cause global warming that reduces welfare in both countries. They find emission taxes and quotas are equivalent, while emission standards lead to over-production of the polluting good. Ishikawa and Kiyono (2006) compare these policy instruments under free trade, but they use a non-strategic setting in which only one country uses environmental policy. Kiyono and Ishikawa (2004) specify a partial equilibrium model in which two large countries import fuel, an input in the production of a final good. Emissions, a by-product of the use of fuel in production, add to global pollution, which reduces welfare in both importing countries. Regulation of emissions only by the home country leads to carbon leakage, as changes in the world price of fuel affect pollution emissions in the other country. Because of strategic effects, they find world pollution is lower when both countries use quotas, rather then taxes, to regulate emissions. In their model the terms of trade and the carbon leakage effect reinforce each other. In general, if these motives work in different directions in any one country, then it is not possible to infer the net effect on pollution and welfare. In our open economy model, with no terms of trade effects in equilibrium, it is purely the carbon leakage effect that drive the results.

We use a two good, two country trade model to analyze the effects of liberalizing trade while leaving domestic policy unconstrained in the presence of transboundary pollution. We assume production of good (X) in either country generates eyesore pollution which reduces

[3] In essence, they assume there are a large number of Northern and a large number of Southern countries.

www.manaraa.com

welfare in both countries. There are three potential distortions in our model: first, there is a production distortion, a domestic externality that drives a wedge between the private and social costs in one sector. Second, countries are large and hence have incentives to manipulate their terms of trade and lastly, the presence of transboundary pollution implies an efficient allocation cannot be achieved when countries practice free trade but set domestic environmental policies non-cooperatively.

Within this framework we compare the effects of environmental taxes and quotas when countries set policy non-cooperatively. We find that, if governments use taxes, the movement from autarky to free trade can result in an equilibrium in which both countries use lower taxes and achieve lower welfare than under autarky. This race to the bottom occurs not because of the terms of trade effect (as there is no trade in equilibrium), but rather because - in a strategic setting in an open economy - the government relaxes environmental taxes to reduce the incidence of transboundary pollution from abroad (i.e., to reduce "carbon leakage" in the free trade equilibrium). This race to the bottom does not occur when (globally nontradable) emission quotas, rather then taxes, are used. However, if international trade in emission permits is allowed, then a race to the bottom will occur if pollution is not a pure global public bad[4]. Thus, we find that in the symmetric free trade equilibrium, pollution is lowest with internationally nontradable quotas and the internationally nontradable emissions quota equilibrium is strictly welfare-superior to the emissions tax equilibrium. The internationally tradable quota equilibrium strictly welfare dominates the tax equilibrium only a under certain condition if pollution is not a pure global public bad; however, the former strictly welfare dominates the latter if pollution is a pure global public bad.

We generalize the model to allow for the case when emissions and production are not necessarily in one-to-correspondence. This model allows for the possibility of polluting and non-polluting inputs and also nests the case of the production of both goods emitting pollution as a by-product. In this generalized framework we find that the results found earlier in the chapter continue to hold.

[4]If the marginal damage in the home country from foreign emissions is positive, but less than that from domestic emissions, then there is transboundary pollution but it is not a pure global public bad.

المنارة للاستشارات

www.manaraa.com

The rest of this chapter is organized as follows. The model is presented in Section 3.2 and Section 3.3 derives the autarky equilibrium. Section 3.4 looks at the efficient equilibrium, while Section 3.5 explores the strategic free trade equilibrium, and compares pollution and welfare under different policy instruments. In Section 3.6 we present a generalization of the model and Section 3.7 concludes the chapter.

3.2 The Model

We conduct our analysis using a standard two good (X, Y) model of trade between two countries, a home country and a foreign country (denoted by *). The production possibility frontier of the home country is

$$g(x, y) \geq 0; \qquad g_i < 0, \quad i = x, y \tag{3.1}$$

The foreign production possibility frontier is similar. Emissions are a by-product of the production of X; good Y does not pollute. We assume that production of one unit of X generates θ units of emissions in the country of production and, due to transboundary pollution, $\hat{\theta}$ units of emissions in the other country. Thus, total pollution in the home and foreign countries are, respectively,

$$Z = \theta x + \hat{\theta} x^*, \quad Z^* = \hat{\theta} x + \theta x^*; \quad \hat{\theta} \in (0, \theta] \tag{3.2}$$

When $\theta > \hat{\theta}$, domestic emissions cause a higher marginal damage in the home country than foreign emissions, while pollution is a pure global public bad if $\theta = \hat{\theta}$.

Let c_x and c_y denote consumption of X and Y in the home country. Preferences of the representative agent in the home country are given by a twice differentiable concave utility function

$$U(c_x, c_y, Z) = \phi(c_x, c_y) - \eta Z; \qquad \phi_{c_x}, \phi_{c_y}, \eta > 0 \tag{3.3}$$

Foreign country preferences are similar.

www.manaraa.com

3.3 Autarky

We first solve the domestic social planner's problem. Assuming home and foreign actions are taken simultaneously, the benevolent home government maximizes its own citizen's welfare, which yields the following optimality condition (since in autarky $x = c_x$ and $y = c_y$)

$$\frac{g_x}{g_y} = \frac{\phi_{c_x} - \eta\theta}{\phi_{c_y}} \tag{3.4}$$

i.e., the domestic rate of transformation equals the social marginal rate of substitution, taking into account the effect of emissions on domestic welfare. However, private agents in the economy do not take into account the domestic distortion in their decision making process. Profit maximization implies

$$\frac{p_x^f}{p_y^f} = \frac{g_x}{g_y} \tag{3.5}$$

where p_x^f and p_y^f are the producer prices of X and Y respectively. Producers equate the domestic rate of transformation to the producer price ratio. Utility maximization by consumers leads to the following optimality condition

$$\frac{p_x^c}{p_y^c} = \frac{\phi_{c_x}}{\phi_{c_y}} \tag{3.6}$$

where p_x^c and p_y^c are the consumer prices of X and Y respectively. Consumers equate the marginal rate of substitution to the consumer price ratio. Comparing the optimality conditions of the social planner, producers and consumers, Eq.s (3.4), (3.5) and (3.6) respectively, it is clear that the best solution is a tax on domestic emissions

$$t_z^a = \frac{\eta}{\phi_{c_y}} \tag{3.7}$$

i.e., a tax on emissions equal to the domestic marginal damage of emissions. Given the one-to-one correspondence between output and emissions, this emission tax is equivalent to a tax on the output of X, which in our case is

$$t^a = \frac{\eta\theta}{\phi_{c_y}} \tag{3.8}$$

Note that this autarky solution is inefficient from the global perspective as governments do not internalize the transboundary effect of their emissions.

المنارة للاستشارات

www.manaraa.com

3.4 Efficient Equilibrium

To obtain Pareto efficient allocations we solve a social planner's problem that maximizes the welfare of the home country subject to meeting a certain utility target for the foreign country. Naturally, the social planner accounts for the domestic and transboundary externalities. The social planner's problem yields the following optimality conditions

$$\frac{\phi_{c_x}}{\phi_{c_y}} = \frac{\phi_{c_x^*}}{\phi_{c_y^*}} \tag{3.9}$$

$$\frac{g_x}{g_y} = \frac{\phi_{c_x}}{\phi_{c_y}} - \left[\frac{\eta\theta}{\phi_{c_y}} + \frac{\eta\hat{\theta}}{\phi_{c_y^*}}\right] \tag{3.10}$$

$$\frac{g_{x^*}}{g_{y^*}} = \frac{\phi_{c_x^*}}{\phi_{c_y^*}} - \left[\frac{\eta\hat{\theta}}{\phi_{c_y}} + \frac{\eta\theta}{\phi_{c_y^*}}\right] \tag{3.11}$$

The marginal rate of substitution is equated across countries and the domestic rate of transformation in each country is equated to the social marginal rate of substitution, taking into account the effect of emissions on both countries. Hence, the Pareto efficient tax on emissions is

$$t_z^e = \left[\frac{\eta}{\phi_{c_y}} + \frac{\eta}{\phi_{c_y^*}}\right]; \qquad t_z^{e*} = \left[\frac{\eta}{\phi_{c_y^*}} + \frac{\eta}{\phi_{c_y}}\right] \tag{3.12}$$

i.e., a tax equal to the sum of marginal damages in the two countries. This tax is equivalent to a tax on the production of the polluting good, X

$$t^e = \left[\frac{\eta\theta}{\phi_{c_y}} + \frac{\eta\hat{\theta}}{\phi_{c_y^*}}\right]; \qquad t^{e*} = \left[\frac{\eta\theta}{\phi_{c_y^*}} + \frac{\eta\hat{\theta}}{\phi_{c_y}}\right] \tag{3.13}$$

Hence, efficiency need not require equalization of environmental taxes across countries, but it does require that both countries internalize the domestic and transboundary effects of emissions[5].

3.5 Free Trade

In this section we analyze the effects of a movement from autarky to free trade and how the choice of the policy instrument governs these effects. We consider each country's optimal

[5]If $\theta > \hat{\theta}$, then $t^e > t^{e*}$ if, and only if, $\phi_{c_y^*} > \phi_{c_y}$.

المنارة للاستشارات
www.manaraa.com

non-cooperative environmental policy, given that they have committed to free trade[6] and that they act simultaneously. We consider three cases: i) governments regulate emissions using a tax on domestic emissions (equivalent to a tax on the production of X), ii) emission (or production) quotas are used to regulate pollution, and these quotas are not tradable across countries, and iii) internationally tradable quotas are the environmental policy instruments. Finally, we compare pollution and welfare under these different instruments.

3.5.1 Taxes

The only policy instrument available to each country is a tax on emissions. Given the one-to-one correspondence between output and emissions, this is equivalent to a tax on the production of X, denoted by t and t^*, and we carry out our analysis in the rest of this section using equivalent production policies. Let p_x and p_y be the (world) consumer prices of X and Y respectively. Let good Y be the numeraire, hence we set $p_y \equiv 1$. The GNP functions for the home and foreign countries are, respectively,

$$R(p_x - t); \qquad R^*(p_x - t^*)$$

The expenditure functions for the home country and the foreign country are[7]

$$e(p_x, u + \eta\{\theta x + \hat{\theta} x^*\}); \qquad e^*(p_x, u^* + \eta\{\hat{\theta} x + \theta x^*\})$$

Equilibrium is described by the income constraints (balance of trade constraints) for the two countries and a market clearing condition:

$$e(p_x, u + \eta\{\theta x + \hat{\theta} x^*\}) = R(p_x - t) + tx \tag{3.14}$$

$$e^*(p_x, u^* + \eta\{\hat{\theta} x + \theta x^*\}) = R^*(p_x - t^*) + t^* x^* \tag{3.15}$$

$$e_{p_x} + e^*_{p_x} = x + x^* \tag{3.16a}$$

$$x = R_{p_x - t} \tag{3.16b}$$

[6]This can be due to trade agreements that restrict the use of trade policies.

[7]Due to the presence of the externality, the expenditure function is given by: $\min_{c_x, c_y}(p_x c_x + c_y)$ s.t. $\phi(c_x, c_y) - \eta Z \geq u \Rightarrow \min_{c_x, c_y}(p_x c_x + c_y)$ s.t. $\phi(c_x, c_y) \geq u + \eta Z$.

المنارة للاستشارات
www.manaraa.com

$$x^* = R^*_{p_x - t^*} \tag{3.16c}$$

where Eq.s (3.14), (3.15) and (3.16) are the resource constraints for the home and foreign countries, and the market clearing condition, respectively. We assume that governments simultaneously and non-cooperatively choose their domestic tax to maximize welfare. Also, all tax revenues are redistributed lump-sum to consumers.

Taking the total differential of Eq.s (3.14) and (3.16b), and combining we have

$$e_u du + (e_u \eta\theta - t)dx + e_u \eta\hat{\theta} dx^* = (R_p - e_{p_x})dp_x; \qquad dx = S'(dp_x - dt) \tag{3.17}$$

where we define $R_{p_x - t}$ as R_p, and R_{pp} as S'. Similarly totally differentiating Eq.s (3.15) and (3.16b), we have

$$e^*_{u^*} du^* + (e^*_{u^*}\eta\theta - t^*)dx^* + e^*_{u^*}\eta\hat{\theta} dx = (R^*_{p^*} - e^*_{p_x})dp_x; \qquad dx^* = S^{*'}(dp_x - dt^*) \tag{3.18}$$

where we define $R^*_{p_x - t^*}$ as $R^*_{p^*}$, and $R^*_{p^*p^*}$ as $S^{*'}$.

Differentiating Eq. (3.14) with respect to t we get the home country's best response function as a function of the foreign country's tax

$$e_u \frac{du}{dt} = (R_p - e_{p_x})\frac{dp_x}{dt} + (t - e_u\eta\theta)\frac{dx}{dt} - e_u\eta\hat{\theta}\frac{dx^*}{dt} \tag{3.19}$$

The first term, the terms of trade effect, depends on whether the country is a net importer of X. The second term is the effect of changes in t on domestic pollution: as t increases, domestic emissions decline. An increase in the domestic environmental tax reduces domestic production of the polluting good resulting, under trade, in an increase in p_x, which increases foreign production and emissions. Thus, the last term is the transboundary pollution effect and reflects the role of carbon leakage.

Similarly the best response function of the foreign country is given by

$$e^*_{u^*}\frac{du^*}{dt^*} = (R^*_{p^*} - e^*_{p_x})\frac{dp_x}{dt^*} + (t^* - e^*_{u^*}\eta\theta)\frac{dx^*}{dt^*} - e^*_{u^*}\eta\hat{\theta}\frac{dx}{dt^*} \tag{3.20}$$

Note that Eq.s (3.19) and (3.20) can also be solved for the optimal autarky production taxes. In autarky domestic production equals domestic consumption, i.e., $R_p(.) = e_{p_x}(.)$, and foreign output is independent of domestic policy, i.e., $\frac{dx^*}{dt} = 0$; hence, from Eq. (3.19) we have

المنارة للاستشارات
www.manaraa.com

$e_u \frac{du}{dt} = (t - e_u\eta\theta)\frac{dx}{dt}$. Since $\frac{dx}{dt} < 0$ and $e_u > 0$, it follows that the optimal autarky tax for the home country is

$$t^a = e_u\eta\theta \quad (3.21)$$

Similarly the optimal autarky tax in the foreign country is

$$t^{a*} = e_u^*\eta\theta \quad (3.22)$$

However, with free trade both x and x^* are affected by the environmental policy in the other country. Totally differentiating Eq. (3.16) yields, after simplification:

$$e_{p_x u}du + e^*_{p_x u^*}du^* + [(\beta + \beta^*) + S'(e_{p_x u}\eta\theta + e^*_{p_x u^*}\eta\hat{\theta}) + S^{*'}(e_{p_x u}\hat{\theta}\eta + e^*_{p_x u^*}\eta\theta)]dp_x$$

$$= [S'(e_{p_x u}\eta\theta + e^*_{p_x u^*}\eta\hat{\theta}) - S']dt + [S^{*'}(e_{p_x u}\eta\hat{\theta} + e^*_{p_x u^*}\eta\theta) - S^{*'}]dt^* \quad (3.23)$$

where we define $\beta \equiv e_{p_x p_x} - S' < 0$ and $\beta^* \equiv e^*_{p_x p_x} - S^{*'} < 0$.

Eq.s (3.17), (3.18) and (3.23) can be written in matrix form as

$$\begin{bmatrix} e_u & 0 & S'(e_u\theta\eta - t) + S^{*'}e_u\eta\hat{\theta} + M_x \\ 0 & e_u^* & S^{*'}(e^*_{u^*}\eta\theta - t^*) + S'e^*_{u^*}\eta\hat{\theta} + M_x^* \\ e_{p_x u} & e^*_{p_x u^*} & (\beta + \beta^*) + S'(e_{p_x u}\eta\theta + e^*_{p_x u^*}\eta\hat{\theta}) + S^{*'}(e_{p_x u}\hat{\theta}\eta + e^*_{p_x u^*}\eta\theta) \end{bmatrix} \begin{bmatrix} du \\ du^* \\ dp_x \end{bmatrix}$$

$$= \begin{bmatrix} S'(e_u\eta\theta - t)dt + S^{*'}e_u\eta\hat{\theta}dt^* \\ S^{*'}(e^*_{u^*}\eta\theta - t^*)dt^* + S'e^*_{u^*}\eta\hat{\theta}dt \\ [S'(e_{p_x u}\eta\theta + e^*_{p_x u^*}\eta\hat{\theta}) - S']dt + [S^{*'}(e_{p_x u}\eta\hat{\theta} + e^*_{p_x u^*}\eta\theta) - S^{*'}]dt^* \end{bmatrix} \quad (3.24)$$

where $M_x = e_{p_x} - R_p$ is the imports of the home country. In equilibrium we have $M_x + M_x^* = 0$. The above system can be inverted and solved. However, to simplify the calculations, we assume quasi-linear preferences (so that the income effect on demand for X is zero, i.e., $e_{p_x u} = e^*_{p_x u^*} = 0$) in the rest of the chapter. Hence, from the third equation in the above system we have

$$\frac{dp_x}{dt} = -\frac{S'}{\beta + \beta^*} > 0$$

Substituting this into the first equation in the above system we have

$$\frac{du}{dt} = \frac{1}{e_u}S'(e_u\eta\theta - t) + \frac{1}{e_u}\left[S'(e_u\eta\theta - t) + S^{*'}e_u\eta\hat{\theta} + M_x\right]\left[\frac{S'}{\beta + \beta^*}\right] \quad (3.25)$$

www.manaraa.com

Note that our model nests the case of no externality, i.e., when $\eta = 0$, and also the case of no transboundary pollution, i.e., $\hat{\theta} = 0$. In the case of no externality, the sign of the above expression depends on M_x. If the country is an importer of X, then $M_x > 0$ implying $\left(\frac{du}{dt}\right)_{t=0} < 0$. Thus the standard terms of trade argument applies, whereby a large country should subsidize domestic production of the importable if the use of commercial policies is prohibited.

Now suppose that the home and foreign countries are identical. Hence, if $t = t^*$ then $M_x = 0$. Evaluating Eq. (3.25) at the autarky solution, $t^a = e_u \eta \theta$, we have

$$\left(\frac{du}{dt}\right)_{t=t^a} = S^{*'} \eta \hat{\theta} \left[\frac{S'}{\beta + \beta^*}\right] < 0 \tag{3.26}$$

Intuitively, the result in Eq. (3.26) follows because increases in domestic taxes increase foreign output and hence foreign pollution, i.e., $\frac{dx^*}{dt} > 0$. Thus, the transboundary pollution effect, in our symmetric model, leads to lower environmental taxes for *both* countries under free trade. We summarize our results in the following proposition

Proposition 1. *If two countries have identical preferences and technology, and t^a is the optimal autarky tax in each country, then under free trade each country's optimal response is to choose a tax rate less than t^a.*

This policy is optimal for both countries. Hence, assuming identical solutions and uniqueness, we have

Proposition 2. *With identical countries, if countries set environmental taxes non-cooperatively but otherwise pursue free trade, then*

1. *there is a race to the bottom in environmental taxes, and*

2. *both countries are worse off under free trade relative to autarky.*

Note that even if the countries are not identical, by continuity, if they are *sufficiently* similar then the above results hold. Thus,

Corollary 1. *If countries are sufficiently similar then a move from autarky to free trade will make both countries worse off if environmental taxes are set non-cooperatively.*

المنارة للاستشارات
www.manaraa.com

An important implication of this is that the more similar countries are, the more likely it is that trade liberalization will lead to lower welfare in *both* countries. The primary role of environmental policies should be regulation of pollution. However, in the absence of tariffs large countries have an incentive to use environmental policies as a secondary trade barrier to manipulate the terms of trade. There is another role for environmental policies in the presence of transboundary pollution; change in world prices due to domestic environmental regulations can increase foreign emissions via carbon leakage, which reduces the benefits from tighter domestic policies. The motive behind the under-regulation of the polluting sector is to reduce transboundary pollution from abroad, which partly offsets the benefits of tighter domestic pollution policies. In equilibrium, in our symmetric model, there is *no terms of trade motive*; it is purely the *transboundary pollution effect*, i.e., the incentive to reduce carbon leakage, that leads countries to lower domestic environmental tax, resulting in a race to the bottom in environmental taxes.

3.5.2 Quotas

Now suppose both governments use command and control policies, such as upper bounds on emissions (or output), instead of taxes. Hence $x \leq L$ and $x^* \leq L^*$, where L and L^* are the production limits in the home and foreign countries, respectively. Governments simultaneously and non-cooperatively choose their quota levels to maximize welfare. Define the (shadow) value of a quota in the home and foreign countries as $\hat{\tau} \equiv p_x - p$ and $\hat{\tau}^* \equiv p_x - p^*$, respectively, where p (p^*) is the producer price of X in the home (foreign) country. If the quotas are auctioned off or traded domestically then $\hat{\tau}$ and $\hat{\tau}^*$ are the market prices of the quotas in the home and foreign countries, respectively. The home and foreign GNP functions are, respectively,

$$R(p_x - \hat{\tau}), \quad \text{with} \quad R_p(p_x - \hat{\tau}) \equiv L; \qquad R^*(p_x - \hat{\tau}^*), \quad \text{with} \quad R^*_{p^*}(p_x - \hat{\tau}^*) \equiv L^*$$

Equilibrium is described by

$$e(p_x, u + \eta\{\theta x + \hat{\theta} x^*\}) = R(p_x - \hat{\tau}) + \hat{\tau} L \tag{3.27}$$

$$e^*(p_x, u^* + \eta\{\hat{\theta} x + \theta x^*\}) = R^*(p_x - \hat{\tau}^*) + \hat{\tau}^* L^* \tag{3.28}$$

المنارة للاستشارات
www.manaraa.com

$$e_{p_x} + e^*_{p_x} = x + x^* \tag{3.29a}$$

$$x = R_{p_x - \hat{\tau}} \leq L \tag{3.29b}$$

$$x^* = R^*_{p_x - \hat{\tau}^*} \leq L^* \tag{3.29c}$$

where Eq.s (3.27), (3.28) and (3.29) are the income constraints for the home and foreign countries, and the market clearing conditions, respectively. The quota rents (revenues) are rebated lump-sum to consumers. We assume that the quotas bind; hence, $\hat{\tau}, \hat{\tau}^* > 0$, and Eq.s (3.29b) and (3.29c) hold with equality.

Taking the total differential of Eq. (3.27) we have

$$e_{p_x} dp_x + e_u du + e_u \eta\theta dx + e_u \eta\hat{\theta} dx^* = R_p(dp_x - d\hat{\tau}) + Ld\hat{\tau} + \hat{\tau} dL;$$

$$dx = dL, \quad \text{and} \qquad R_p(p_x - \hat{\tau}) = L \tag{3.30}$$

Similarly totally differentiating Eq. (3.28) we have

$$e^*_{p_x} dp_x + e^*_{u^*} du^* + e^*_{u^*} \eta\theta dx^* + e^*_{u^*} \eta\hat{\theta} dx = R^*_{p^*}(dp_x - d\hat{\tau}^*) + L^* d\hat{\tau}^* + \hat{\tau}^* dL^*;$$

$$dx^* = dL^*, \quad \text{and} \quad R^*_{p^*}(p_x - \hat{\tau}^*) = L^* \tag{3.31}$$

Differentiating Eq. (3.27) with respect to L gives the home country's best response function as a function of the foreign country's quota

$$e_u \frac{du}{dL} = (R_p - e_{p_x}) \frac{dp_x}{dL} + (\hat{\tau} - e_u \eta\theta) \frac{dx}{dL} - e_u \eta\hat{\theta} \frac{dx^*}{dL} \tag{3.32}$$

The first and second terms are the terms of trade and domestic pollution effects, respectively, while the last term is the effect of changes in the incidence of transboundary pollution on domestic welfare. The terms of trade effect depends on whether the polluting good is an import of the home country. Issuing an additional permit, given that the quota binds, increases domestic production and domestic emissions. If foreign production changes following changes in domestic quotas, then it affects domestic welfare via a change in the incidence of transboundary pollution.

المنارة للاستشارات
www.manaraa.com

The foreign country's best response function is given by

$$e^*_{u^*}\frac{du^*}{dL^*} = (R^*_{p^*} - e^*_{p_x})\frac{dp_x}{dL^*} + (\hat{\tau}^* - e^*_{u^*}\eta\theta)\frac{dx^*}{dL^*} - e^*_{u^*}\eta\hat{\theta}\frac{dx}{dL^*} \tag{3.33}$$

Eq.s (3.32) and (3.33) can be solved for the optimal autarky production quotas. In autarky domestic consumption equals domestic production and the quota binds, i.e., $e_{p_x}(.) = R_p(.) = L$, and foreign output is independent of domestic policy, i.e., $\frac{dx^*}{dL} = 0$; hence, from Eq. (3.30), we have $e_u\frac{du}{dL} = \hat{\tau} - e_u\eta\theta$. Since $e_u > 0$, the domestic production tax equivalent of the optimal autarky production quota for the home country is

$$\hat{\tau}^a = e_u\eta\theta \tag{3.34}$$

Similarly, the production tax equivalent of the optimal autarky output quota for the foreign country is

$$\hat{\tau}^{a*} = e^*_{u^*}\eta\theta \tag{3.35}$$

Now consider each country's optimal non-cooperative environmental policy, given a commitment to free trade. Let x^a and x^{a*} be the autarky output (quota) levels in the home and foreign countries, respectively. Further, suppose that the countries are identical. Hence, if $\hat{\tau}, \hat{\tau}^* > 0$, $L = x^a = x^{a*} = L^*$, then $\exists N(x^a)$ such that, for $L \in N[x^a]$, L^* binds. Hence

$$\left(\frac{dx^*}{dL}\right)_{L=x^a} = 0 \tag{3.36}$$

If $L^* = x^{a*} = x^a = L$, then at $L = x^a$, $x(L, L^*) = x^a = e_{p_x}$, i.e., $L = R_p(.) = e_{p_x}(.)$. Evaluating Eq. (3.32) at the autarky solution, $L = x^a$, we have

$$\left(\frac{du}{dL}\right)_{L=x^a} = 0 \tag{3.37}$$

Hence, for our symmetric specification, the optimal domestic output and the equivalent output tax are the same in the free trade equilibrium as in the autarky equilibrium. We summarize our result in the following proposition

Proposition 3. *Suppose governments use pollution (or production) limits, rather than taxes to regulate pollution. Then, in the symmetric equilibrium, the autarky and free trade equilibria will be the same and there is no race to the bottom in environmental policy.*

المنارة للاستشارات
www.manaraa.com

To see why this result follows, suppose the foreign government imposes an upper bound on emissions (output) equal to the autarky level, i.e., it regulates output such that $x^* \leq L^* = x^{a^*}$. For any domestic output $x < x^a$, the reduced world output of good x (compared to the autarky situation) results in higher consumer (hence, producer) prices than in the (symmetric) autarky equilibrium and so the foreign output upper bound will bind. As the home country increases its permissible output limit, L, in the domain $L < x^a$, the foreign production limit continues to bind and thus $\frac{dx^*}{dL} = 0$ in the domain $L < x^a$. Furthermore, at $L = x^a$, a (small) increase in L leads to a (small) decline in world consumer prices (to below autarkic levels) but foreign output is still not affected because the consumer price is above the producer price[8]. Hence, in the neighborhood of $L = x^a$, we have $\frac{dx^*}{dL} = 0$, i.e., changes in the domestic quota level do not affect foreign output (hence, foreign emissions). Recall that the driving force behind the race to the bottom in taxes was the motive to reduce the incidence of transboundary pollution. Since changes in domestic policy do not influence foreign emissions, countries follow the same policies as in autarky. Thus, although typically there is a presumption that price-based policies are superior to command and control policies, in a strategic setting that need not be the case, and the equivalence between the two in closed economies breaks down with the possibility of trade between countries.

3.5.3 Tradable Quotas

We analyze the interaction between goods trade and permit trade, and consider the situation in which governments regulate emissions using quotas but, following Copeland and Taylor (1995), these quotas are tradable across the countries, i.e., countries practice free trade not only in goods, but also in permits. Thus, producer prices of goods and market values of quotas are equalized across countries, i.e., $p = p^* = p_x - \tau$, where τ is the market price of production quotas. Governments simultaneously and non-cooperatively choose quota limits to maximize

[8] The market value of the foreign production quota, if tradable, will fall but remain positive, as the increase in domestic output of x lowers the gap between the demand and supply price. However, this has no impact on the home economy and, due to symmetry, the terms of trade effect around $L = x^a$ are zero.

المنارة للاستشارات
www.manaraa.com

welfare. Equilibrium is now described by

$$e(p_x, u + \eta\{\theta x + \hat{\theta} x^*\}) = R(p_x - \tau) + \tau L \tag{3.38}$$

$$e^*(p_x, u^* + \eta\{\hat{\theta} x + \theta x^*\}) = R^*(p_x - \tau) + \tau L^* \tag{3.39}$$

$$e_{p_x} + e^*_{p_x} = x + x^* \tag{3.40a}$$

$$x + x^* = R_{p_x - \tau} + R^*_{p_x - \tau} \leq L + L^* \tag{3.40b}$$

where Eq.s (3.38), (3.39) and (3.40) are the balance of trade constraints for the home and foreign countries, and the market clearing conditions, respectively. We assume that the quotas bind; hence, $\tau > 0$ and

$$e_{p_x} + e^*_{p_x} = R_{p_x - \tau} + R^*_{p_x - \tau} = L + L^* \tag{3.41}$$

Note that, as shown in the previous section, the production tax equivalent of the optimal autarky quota in the home and foreign countries are, respectively, $\tau^a = e_u \eta \theta$ and $\tau^{a*} = e^*_{u^*} \eta \theta$.

Taking the total differential of Eq. (3.38) we have

$$e_{p_x} dp_x + e_u du + e_u \eta \theta dx + e_u \eta \hat{\theta} dx^* = R_p (dp_x - d\tau) + L d\tau + \tau dL;$$

$$dx + dx^* = dL + dL^*, \quad \text{and} \quad R_p(p_x - \tau) + R^*_p(p_x - \tau) = L + L^* \tag{3.42}$$

Totally differentiating Eq. (3.39) we get

$$e^*_{p_x} dp_x + e^*_{u^*} du^* + e^*_{u^*} \eta \theta dx^* + e^*_{u^*} \eta \hat{\theta} dx = R^*_p (dp_x - d\tau) + L^* d\tau + \tau dL^*;$$

$$dx + dx^* = dL + dL^*, \quad \text{and} \quad R_p(p_x - \tau) + R^*_p(p_x - \tau) = L + L^* \tag{3.43}$$

The best response function of the home country in terms of the foreign country's quota is derived by differentiating Eq. (3.38) with respect to L

$$e_u \frac{du}{dL} = (R_p - e_{p_x}) \frac{dp_x}{dL} + (L - R_p) \frac{d\tau}{dL} + (\tau - e_u \eta \theta) \frac{dx}{dL} + (\tau - e_u \eta \hat{\theta}) \frac{dx^*}{dL} \tag{3.44}$$

The net domestic welfare effect of issuing an additional quota depends on a number of different effects. The first term, the terms of trade effect, depends on the pattern of trade, while the

المنارة للاستشارات
www.manaraa.com

second term is the quota revenue effect. The third term is the effect on domestic welfare through changes in domestic emissions: if some of the new quotas are used domestically, then domestic emissions increase. The last term, the transboundary pollution effect, depends on whether foreign production increases with an increase in domestic quotas and on the public bad characteristic of pollution.

The foreign country's best response function is

$$e^*_{u^*}\frac{du^*}{dL^*} = (R^*_p - e^*_{p_x})\frac{dp_x}{dL^*} + (L^* - R^*_p)\frac{d\tau}{dL^*} + (\tau - e^*_{u^*}\eta\theta)\frac{dx^*}{dL^*} + (\tau - e^*_{u^*}\eta\hat{\theta})\frac{dx}{dL^*} \tag{3.45}$$

Differentiating Eq. (3.41) with respect to L we have[9]

$$\frac{dp_x}{dL} = \frac{dp_x}{dL^*} = \frac{1}{e_{p_x p_x} + e^*_{p_x p_x}} < 0 \tag{3.46}$$

and

$$\frac{dp_x}{dL} - \frac{d\tau}{dL} = \frac{1}{S' + S^{*\prime}} \tag{3.47}$$

Furthermore, $x^* = R^*_p(p_x - \tau)$ implies (using Eq. (3.47))

$$\frac{dx^*}{dL} = S^{*\prime}(\frac{dp_x}{dL} - \frac{d\tau}{dL}) = \frac{S^{*\prime}}{S' + S^{*\prime}} \in (0, 1) \tag{3.48}$$

Suppose, as before, that the countries are identical; hence, if $L = x^a = x^{a*} = L^*$, then $e_{p_x}(.) = R_p(.) = L$. Evaluating Eq. (3.44) at the autarky solution, $L = x^a$, we have

$$\left(e_u\frac{du}{dL}\right)_{L=x^a} = \left(\tau^a - e_u\eta\hat{\theta}\right)\frac{dx^*}{dL} \tag{3.49}$$

$(\tau^a - e_u\eta\hat{\theta}) > 0$ if $\theta > \hat{\theta}$, and Eq. (3.48) $\Rightarrow \frac{dx^*}{dL} > 0$; thus, Eq. (3.49) implies (since $e_u > 0$)

$$\left(\frac{du}{dL}\right)_{L=x^a} > 0 \quad \text{if} \quad \theta > \hat{\theta} \tag{3.50}$$

We summarize our result in the following proposition

Proposition 4. *If two countries have identical preferences and technology, and if domestic emissions result in a higher marginal damage than transboundary pollution, i.e., if $\theta > \hat{\theta}$, then under free trade in both goods and emission (or production) permits, each country's optimal response is to choose a quota level higher than the equilibrium autarky level, L^a.*

[9] Recall that we assume quasi-linear preferences, so $e_{p_x u} = e^*_{p_x u^*} = 0$.

المنارة للاستشارات
www.manaraa.com

As this policy is optimal for both countries, assuming identical solutions and uniqueness, we have the following

Proposition 5. *With identical countries, if the marginal damage from domestic emissions is higher than that from transboundary pollution, i.e., if $\theta > \hat{\theta}$, and countries set production (or emission) quotas non-cooperatively but otherwise pursue free trade in goods and permits, then*

1. *there is a race to the bottom in environmental policy, and*

2. *both countries are worse off under free trade relative to autarky.*

If the countries are not identical, as long as they are *sufficiently* similar, then, by continuity, the above results hold.

Corollary 2. *If countries are sufficiently similar and emission (or production) quotas are set non-cooperatively, then a move from autarky to free trade in both goods and quotas will make both countries worse off if the marginal damage from domestic emissions is higher than that from transboundary pollution, i.e., if $\theta > \hat{\theta}$.*

Thus, the more similar countries are, the more likely it is that *both* countries will relax their environmental policies and *both* will lose from trade liberalization, if $\theta > \hat{\theta}$. Note that with identical countries, assuming identical and unique solutions, Eq. (3.49) implies

$$\left(\frac{du}{dL}\right)_{L=x^a} = 0 \quad \text{if} \quad \hat{\theta} = \theta \tag{3.51}$$

Thus, we have

Proposition 6. *If pollution is a pure global public bad, i.e., if $\theta = \hat{\theta}$, then, in the symmetric equilibrium of this model, the free trade equilibrium with tradable permits is the same as the autarky and nontradable permit equilibria and there is no race to the bottom in environmental policy.*

Proposition 6 reflects the result in Copeland and Taylor (1995) where, due to the pure global public bad nature of pollution, the strategic and non-strategic free trade equilibria coincide. In autarky, issuing an additional permit results in an accompanying increase in

المنارة للاستشارات
www.manaraa.com

pollution by θ units, given that the quota binds. However, with free trade in goods and permits, issuing an additional quota leads to a less than proportional increase in domestic production as some of the additional quotas are used in the foreign country; now pollution increases by $\theta - \frac{S^{*\prime}}{S' + S^{*\prime}}(\theta - \hat{\theta}) < \theta$ if $\theta > \hat{\theta}$. This leads to a race to the bottom in pollution policies. However, if pollution is a pure global public bad, i.e., if $\hat{\theta} = \theta$, the source of emissions does not matter as the marginal damage is the same irrespective of the origin of pollution. Hence, there is no incentive to shift emissions to the other country and there is no race to the bottom.

In Kiyono and Okuno-Fujiwara (2003) countries, by assumption, do not trade and taxes and quotas are found to be equivalent. However, this equivalence breaks down in open economies, even if there is no trade in equilibrium, due to carbon leakage and the strategic interaction among countries. This highlights how results that hold in a closed economy setting do not necessarily hold in an open economy setting even if there is no trade in equilibrium. Furthermore, in our model the only driving force is the carbon leakage effect. In previous models, including Kiyono and Ishikawa (2004), there have been other motives at play in equilibrium, but we have isolated the pure effects of carbon leakage and how the choice of policy instrument affects the outcome of a strategic game.

3.5.4 Pollution and Welfare

In this section we derive the optimal (equivalent) taxes and compare welfare under different policy instruments. The optimal production tax under autarky is $t^a = e_u \eta \theta$, while the Pareto efficient tax is

$$t^e = e_u \eta \theta + e^*_{u*} \eta \hat{\theta} > t^a \tag{3.52}$$

In autarky taxes and quotas are equivalent, i.e.,

$$t^a = \hat{\tau}^a = \tau^a = e_u \eta \theta \tag{3.53}$$

Hence, we have

Proposition 7. *Under autarky the choice of policy instrument to regulate pollution does not matter, i.e., environmental taxes and quotas are equivalent.*

المنارة للاستشارات

www.manaraa.com

This result is similar to Kiyono and Okuno-Fujiwara (2003), who find that in closed economies, emission taxes and quotas are equivalent. When the policy instrument is an environmental tax, the optimal production tax for the home country can be calculated using Eq. (3.25). Setting $\frac{du}{dt} = 0$, we have the optimal free trade production tax

$$t = e_u \eta \theta + \frac{S^{*'} e_u \eta \hat{\theta} + M_x}{e_{p_x p_x} + \beta^*}$$

As before, assuming identical countries, and identical and unique solutions, we have $M_x = 0$ and

$$t = e_u \eta \theta + \frac{S^{*'} e_u \eta \hat{\theta}}{e_{p_x p_x} + \beta^*} < t^a \tag{3.54}$$

With internationally nontradable permits, assuming identical countries, the autarky and free trade equilibria coincide, and the production tax equivalent of the optimal free trade quota is

$$\hat{\tau} = e_u \eta \theta = t^a \tag{3.55}$$

Finally, with internationally tradable permits, the production tax equivalent of the optimal free trade quota can be found by equating $\frac{du}{dL}$ to zero in Eq. (3.44)

$$\tau = e_u \eta \theta + \frac{e_{p_x} - R_p}{e_{p_x p_x} + e^*_{p_x p_x}} + \frac{(L - R_p)(\beta + \beta^*)}{(e_{p_x p_x} + e^*_{p_x p_x})(S' + S^{*'})} + \frac{S^{*'}}{S' + S^{*'}}(e_u \eta \hat{\theta} - e_u \eta \theta)$$

Again, assuming identical countries, and identical and unique solutions, we have $e_{p_x}(.) = R_p(.) = L$, which implies that the production tax equivalent of the optimal free trade quota is

$$\tau = e_u \eta \theta + \frac{S^{*'}}{S' + S^{*'}}(e_u \eta \hat{\theta} - e_u \eta \theta) \tag{3.56}$$

If $\theta > \hat{\theta}$, i.e., if pollution is not a pure global public bad, then $\tau < t^a$, while $\tau = t^a$ if $\theta = \hat{\theta}$. Furthermore, it is straightforward to verify that $\tau > (<)\ t$ if $\frac{\theta}{\hat{\theta}} < (>)\ 1 - \frac{S' + S^{*'}}{e_{p_x p_x} + \beta^*}$.

The optimal (equivalent) environmental taxes in the different cases are related as follows

$$\begin{aligned}
t^e > t^a = \hat{\tau} \quad &= \quad \tau > t \qquad \text{if} \quad \frac{\theta}{\hat{\theta}} = 1 \\
t^e > t^a = \hat{\tau} \quad &> \quad \tau > t \qquad \text{if} \quad 1 < \frac{\theta}{\hat{\theta}} < 1 - \frac{S' + S^{*'}}{e_{p_x p_x} + \beta^*} \\
t^e > t^a = \hat{\tau} \quad &> \quad t > \tau \qquad \text{if} \quad \frac{\theta}{\hat{\theta}} > 1 - \frac{S' + S^{*'}}{e_{p_x p_x} + \beta^*}
\end{aligned} \tag{3.57}$$

We summarize our results in the following proposition

www.manaraa.com

Proposition 8. *If identical countries simultaneously and non-cooperatively choose pollution policies but otherwise pursue free trade, then*

1. *if pollution is a pure global public bad, i.e., if $\hat{\theta} = \theta$, then the (equivalent) environmental tax in the internationally tradable and nontradable quota is the same and is higher than the case when countries use taxes to regulate pollution;*

2. *if pollution is not a pure global public bad, i.e., if $\theta > \hat{\theta}$, then the (equivalent) environmental tax rate is the highest (equal to the autarkic level) when internationally nontradable quotas are the policy instruments; the (equivalent) tax rate is higher (lower) under internationally tradable quotas as compared to the situation in which taxes are used to regulate pollution if $\frac{\theta}{\hat{\theta}} < (>)\ 1 - \frac{S' + S^{*'}}{e_{p_x p_x} + \beta^*}$;*

3. *if pollution is not a pure global public bad, i.e., if $\theta > \hat{\theta}$, pollution is the lowest (equal to the autarkic level) when internationally nontradable quotas are the policy instruments and pollution is the highest when the countries use taxes (internationally tradable quotas) to regulate pollution if, in addition, $\frac{\theta}{\hat{\theta}} < (>)\ 1 - \frac{S' + S^{*'}}{e_{p_x p_x} + \beta^*}$.*

Given our symmetric specification, and that no trade takes place in equilibrium, it follows that welfare (W) under the different policy instruments can be ranked as follows

$$
\begin{aligned}
W^{\text{efficient}} > W^{\text{autarky}} = W^{\text{quota}} &= W^{\text{tradable quota}} > W^{\text{tax}} \quad \text{if} \quad \frac{\theta}{\hat{\theta}} = 1 \\
W^{\text{efficient}} > W^{\text{autarky}} = W^{\text{quota}} &> W^{\text{tradable quota}} > W^{\text{tax}} \quad \text{if} \quad 1 < \frac{\theta}{\hat{\theta}} < 1 - \frac{S' + S^{*'}}{e_{p_x p_x} + \beta^*} \\
W^{\text{efficient}} > W^{\text{autarky}} = W^{\text{quota}} &> W^{\text{tax}} > W^{\text{tradable quota}} \quad \text{if} \quad \frac{\theta}{\hat{\theta}} > 1 - \frac{S' + S^{*'}}{e_{p_x p_x} + \beta^*}
\end{aligned}
$$

Hence,

Proposition 9. *If identical countries simultaneously and non-cooperatively choose pollution policies but otherwise pursue free trade, then*

1. *if pollution is a pure global public bad, i.e., if $\hat{\theta} = \theta$, the internationally nontradable and tradable quota equilibria are equivalent to the autarky equilibrium, and strictly welfare-dominate the tax equilibrium;*

المنارة للاستشارات
www.manaraa.com

2. if the marginal damage from domestic emissions is higher than that from transboundary pollution, i.e., if $\theta > \hat{\theta}$, the internationally nontradable quota equilibrium is equivalent to the autarky equilibrium and strictly welfare-superior to the internationally tradable quota equilibrium and the tax equilibrium; the internationally tradable quota equilibrium strictly welfare dominates (is strictly welfare dominated by) the tax equilibrium if $\frac{\theta}{\hat{\theta}} < (>) 1 - \frac{S' + S^{*\prime}}{e_{p_x p_x} + \beta^*}$.

3.6 Generalization

In this section we retain our assumptions regarding preferences, but generalize the production possibility function used above such that emissions and output are not necessarily in one-to-one correspondence. The model presented here nests the case in which pollution is generated as a by-product of production of both goods. It also allows for substitutability between inputs that can reduce emissions, the possibility of abatement and having polluting as well as non-polluting inputs. Given this generalization, in this section we consider policies on emissions, i.e., pollution taxes and quotas. However, we maintain our earlier assumption of quasi-linear preferences, so that the income effect on demand for X is zero, i.e., $e_{pu} = e^*_{pu^*} = 0$, where p is the consumer price of good X. We start by describing the structure of the model and then analyze the effects of a movement from autarky to free trade under different policy instruments.

We assume, as before, that Y is the numeraire good, hence, $p_y \equiv 1$. The production possibility frontier of the home country is

$$g(x, y, z; \overrightarrow{V}) \geq 0; \qquad g_x < 0, g_y < 0, g_z > 0, g_{v_i} > 0 \tag{3.58}$$

where z is pollution and $\overrightarrow{V}$ is the vector of inputs. The foreign country's production possibility frontier is similar.

Total pollution in the home and foreign countries are, respectively,

$$Z = \theta z + \hat{\theta} z^*, \quad Z^* = \hat{\theta} z + \theta z^*; \quad \hat{\theta} \in (0, \theta] \tag{3.59}$$

المنارة للاستشارات

www.manaraa.com

Preferences of the representative agent are the same as in the rest of the chapter and the home country's utility function is repeated here for convenience

$$U(c_x, c_y, Z) = \phi(c_x, c_y) - \eta Z; \qquad \phi_{c_x}, \phi_{c_y}, \eta > 0$$

Let us now consider the effects of trade liberalization on pollution and welfare under different policy instruments. As in the rest of the chapter, we consider three different policy instruments[10]: i) countries tax domestic emissions to regulate pollution, ii) the policy instrument is internationally nontradable pollution quotas, and iii) governments use emission quotas to regulate pollution, but these quotas are tradable across countries.

3.6.1 Taxes

The only policy instrument available to each government is a tax on emissions. Let t_z and t_z^* denote the pollution taxes in the home and foreign countries, respectively. Equilibrium is described by the balance of trade constraints for the two countries and a market clearing condition:

$$e(p, u + \eta\{\theta z + \hat{\theta} z^*\}) = R(p, t_z) + t_z z \tag{3.60}$$

$$e^*(p, u^* + \eta\{\hat{\theta} z + \theta z^*\}) = R^*(p, t_z^*) + t_z^* z^* \tag{3.61}$$

$$e_p + e_p^* = x + x^* \tag{3.62a}$$

$$x = R_p, \quad x^* = R_p^* \tag{3.62b}$$

$$z = -R_{t_z}, \quad z^* = -R^*_{t_z^*} \tag{3.62c}$$

where Eq.s (3.60), (3.61) and (3.62) are the resource constraints for the home and foreign countries, and the market clearing conditions, respectively; p (p^*) and t_z (t_z^*) are the price of X and the pollution tax in the home (foreign) country, respectively. We assume that governments simultaneously and non-cooperatively choose their domestic tax to maximize welfare. Furthermore, all tax revenues are redistributed lump-sum to consumers.

[10]Note that, in this section, pollution and output policies are no longer equivalent, so we carry out our analysis using pollution policies.

المنارة للاستشارات
www.manaraa.com

Differentiating the home country's resource constraint, Eq. (3.60), with respect to t_z gives us the home country's best response function as a function of the foreign country's tax

$$e_u \frac{du}{dt_z} = (R_p - e_p)\frac{dp}{dt_z} + (t_z - e_u\eta\theta)\frac{dz}{dt_z} - e_u\eta\hat{\theta}\frac{dz^*}{dt_z} \tag{3.63}$$

The first term, the terms of trade effect, depends on whether the country is a net importer of X and the pollution intensity of X which, in turn, determines the direction of change in the price of X due to a change in the pollution tax, t_z. The second term is the effect of changes in t_z on domestic pollution: as t_z increases, domestic emissions decline. An increase in the domestic environmental tax reduces domestic production of the pollution intensive good resulting, under trade, in an increase in the world price of that good, which increases foreign production and emissions. Thus, the last term reflects the transboundary pollution effect.

Similarly, the best response function of the foreign country is

$$e^*_{u^*} \frac{du^*}{dt^*_z} = (R^*_p - e^*_p)\frac{dp^*}{dt^*_z} + (t^*_z - e^*_{u^*}\eta\theta)\frac{dz^*}{dt^*_z} - e^*_{u^*}\eta\hat{\theta}\frac{dz}{dt^*_z} \tag{3.64}$$

Note that Eq.s (3.63) and (3.64) can also be solved for the optimal autarky pollution taxes. In autarky domestic production equals domestic consumption, i.e., $R_p(.) = e_p(.)$, and foreign pollution is independent of domestic policy, i.e., $\frac{dz^*}{dt_z} = 0$; hence, from Eq. (3.63) we have $e_u \frac{du}{dt_z} = (t_z - e_u\eta\theta)\frac{dz}{dt}$. Since $\frac{dz}{dt} < 0$ and $e_u > 0$, it follows that the optimal autarky pollution tax for the home country is

$$t^a_z = e_u\eta\theta \tag{3.65}$$

Similarly, the optimal autarky pollution tax in the foreign country is

$$t^{a*}_z = e^*_u\eta\theta \tag{3.66}$$

Under free trade both z and z^* are affected by the environmental policy in the other country. Differentiating Eq. (3.62a) with respect to t_z yields

$$\frac{dp}{dt_z} = \frac{R_{pt_z}}{\beta + \beta^*} \tag{3.67}$$

where, as in previous sections, $\beta = e_{pp} - R_{pp}$ and $\beta^* = e^*_{pp} - R^*_{pp}$. Hence, $\frac{dp}{dt_z} > 0$ if X is relatively more pollution intensive, i.e., if $R_{pt_z} < 0$ (since $(\beta + \beta^*) < 0$). Furthermore,

المنارة للاستشارات
www.manaraa.com

the change in foreign pollution due to a change in the home country's pollution tax is $\frac{dz^*}{dt_z} = \frac{dz^*}{dp}\frac{dp}{dt_z} = -R^*_{pt^*_z}\frac{dp}{dt_z}$, and using Eq. (3.67) we have

$$\frac{dz^*}{dt_z} = -\frac{R^*_{pt^*_z} R_{pt_z}}{\beta + \beta^*} \tag{3.68}$$

Since $(\beta + \beta^*) < 0$, $\frac{dz^*}{dt_z} > 0$ under symmetry, irrespective of whether X or Y is relatively more pollution intensive.

In the case of no externality, i.e., if $\eta = 0$, the home country's best response function, Eq. (3.63), reduces to

$$e_u \frac{du}{dt_z} = (R_p - e_p)\frac{dp}{dt_z} + t_z \frac{dz}{dt_z}$$

If the home country is a net importer of X ($M_x > 0$), and X is pollution intensive, i.e., $R_{pt_z} < 0$, then $\frac{dp}{dt_z} > 0$ and $\left(\frac{du}{dt_z}\right)_{t_z=0} < 0$. This is the standard terms of trade argument in effect which implies that, when commercial policies are not available, a large country should subsidize domestic production of the importable.

Now consider the case of a transboundary pollution externality and suppose that the home and foreign countries are identical. Thus, if $t_z = t^*_z$, then $M_x = 0$. Evaluating Eq. (3.63) at the autarky solution, $t^a_z = e_u \eta \theta$, we have

$$\left(\frac{du}{dt_z}\right)_{t_z = t^a_z} = \eta \hat{\theta} \left[\frac{R_{pt_z} R^*_{pt^*_z}}{\beta + \beta^*}\right] < 0 \tag{3.69}$$

The result in Eq. (3.69) follows because increases in domestic taxes increase foreign pollution, i.e., $\frac{dz^*}{dt_z} > 0$. Hence, due to the transboundary pollution effect, each country's optimal response is to lower the pollution tax under free trade as compared to autarky. This results in a race to the bottom in pollution taxes that leaves *both* countries worse off due to trade liberalization. Note that, even if countries are not identical, by continuity, our results hold provided the countries are *sufficiently* similar.

3.6.2 Quotas

Now consider the case when both countries use pollution quotas to regulate domestic pollution. Let L_z and L^*_z denote the home and foreign quota levels, respectively. Define the (shadow)

المنارة للاستشارات
www.manaraa.com

value of a quota in the home (foreign) country as $\hat{\tau}_z$ ($\hat{\tau}_z^*$). Equilibrium is now described by

$$e(p, u + \eta\{\theta z + \hat{\theta} z^*\}) = R(p, \hat{\tau}_z) + \hat{\tau}_z L_z \tag{3.70}$$

$$e^*(p, u^* + \eta\{\hat{\theta} z + \theta z^*\}) = R^*(p, \hat{\tau}_z^*) + \hat{\tau}_z^* L_z^* \tag{3.71}$$

$$e_p + e_p^* = x + x^* \tag{3.72a}$$

$$x = R_p, \quad x^* = R_p^* \tag{3.72b}$$

$$z = -R_{\hat{\tau}_z} \leq L_z, \quad z^* = -R^*_{\hat{\tau}_z^*} \leq L_z^* \tag{3.72c}$$

where Eq.s (3.70), (3.71) and (3.72) are the resource constraints for the home and foreign countries, and the market clearing conditions, respectively. The quota rents (revenues) are rebated lump-sum to consumers. We assume that the quotas bind; hence, $\hat{\tau}_z, \hat{\tau}_z^* > 0$, and Eq. (3.72c) holds with equality.

The best response function of the home country in terms of the foreign country's quota is derived by differentiating Eq. (3.70) with respect to L_z

$$e_u \frac{du}{dL_z} = (R_p - e_p)\frac{dp}{dL_z} + (\hat{\tau}_z - e_u \eta\theta)\frac{dz}{dL_z} - e_u \eta\hat{\theta}\frac{dz^*}{dL_z} \tag{3.73}$$

The first and second terms are the terms of trade and domestic pollution effects, respectively, while the last term is the transboundary pollution effect. If foreign production changes following changes in domestic quotas, then it affects domestic welfare via a change in the incidence of transboundary pollution.

The foreign country's best response function is

$$e_{u^*}^* \frac{du^*}{dL_z^*} = (R_p^* - e_p^*)\frac{dp}{dL_z^*} + (\hat{\tau}_z^* - e_{u^*}^* \eta\theta)\frac{dz^*}{dL_z^*} - e_{u^*}^* \eta\hat{\theta}\frac{dz}{dL_z^*} \tag{3.74}$$

Eq.s (3.73) and (3.74) can be solved for the optimal autarky pollution quotas. In autarky domestic consumption equals domestic production, i.e., $e_p(.) = R_p(.)$, the quota binds, i.e., $z = L_z$, and foreign pollution is independent of domestic policy, i.e., $\frac{dz^*}{dL_z} = 0$; hence, from Eq. (3.73), we have $e_u \frac{du}{dL_z} = \hat{\tau}_z - e_u \eta\theta$. Since $e_u > 0$, the domestic pollution tax equivalent of the optimal autarky pollution quota for the home country is

$$\hat{\tau}_z^a = e_u \eta\theta \tag{3.75}$$

المنارة للاستشارات
www.manaraa.com

Similarly, the pollution tax equivalent of the optimal autarky pollution quota for the foreign country is

$$\hat{\tau}_z^{a*} = e_{u^*}^* \eta \theta \tag{3.76}$$

Now consider each country's optimal non-cooperative environmental policy, given a commitment to free trade. Let z^a and z^{a*} be the autarky pollution (quota) levels in the home and foreign countries, respectively. Furthermore, suppose that the countries are identical. Hence, if $\hat{\tau}_z, \hat{\tau}_z^* > 0$, $L_z = z^a = z^{a*} = L_z^*$, then $\exists N(z^a)$ such that, for $L_z \in N[z^a]$, L_z^* binds. Hence

$$\left(\frac{dz^*}{dL_z}\right)_{L_z = z^a} = 0 \tag{3.77}$$

If $L_z^* = z^{a*} = z^a = L_z$, then at $L_z = z^a$, $z(L_z, L_z^*) = z^a$, and $R_p(.) = e_p(.)$. Thus, evaluating Eq. (3.73) at the autarky solution, $L_z = z^a$, we have

$$\left(\frac{du}{dL_z}\right)_{L_z = z^a} = 0 \tag{3.78}$$

Hence, for our symmetric specification, the optimal domestic quota and the equivalent pollution tax are the same in the free trade and autarky equilibrium.

3.6.3 Tradable Quotas

Now we consider the situation in which countries use emission quotas to regulate pollution; however, these quotas are tradable across countries. Hence, the market price of pollution quotas, τ_z, is equalized across countries. Governments simultaneously and non-cooperatively choose their quota levels to maximize welfare. The equilibrium conditions are

$$e(p, u + \eta\{\theta z + \hat{\theta} z^*\}) = R(p, \tau_z) + \tau_z L_z \tag{3.79}$$

$$e^*(p, u^* + \eta\{\hat{\theta} z + \theta z^*\}) = R^*(p, \tau_z) + \tau_z L_z^* \tag{3.80}$$

$$e_p + e_p^* = x + x^* = R_p + R_p^* \tag{3.81a}$$

$$z + z^* = -R_{\tau_z} - R_{\tau_z}^* \leq L_z + L_z^* \tag{3.81b}$$

المنارة للاستشارات
www.manaraa.com

where Eq.s (3.79), (3.80) and (3.81) are the balance of trade constraints for the home and foreign countries, and the market clearing conditions, respectively. We assume that the quotas bind; hence, $\tau_z > 0$ and

$$-R_{\tau_z} - R^*_{\tau_z} = L_z + L^*_z \tag{3.82}$$

Differentiating Eq. (3.79) with respect to L_z gives us the best response function of the home country in terms of the foreign country's quota

$$e_u \frac{du}{dL_z} = (R_p - e_p)\frac{dp}{dL_z} + (L + R_{\tau_z})\frac{d\tau_z}{dL_z} + (\tau_z - e_u\eta\theta)\frac{dz}{dL_z} + (\tau_z - e_u\eta\hat{\theta})\frac{dz^*}{dL_z} \tag{3.83}$$

The net domestic welfare effect of issuing an additional quota depends on four different effects. The first term is the terms of trade effect, while the second term is the quota revenue effect. The third term is the effect on domestic welfare through changes in domestic emissions: if some of the new quotas are used domestically, then domestic emissions increase. The last term, the transboundary pollution effect, depends on whether foreign pollution increases with an increase in domestic quotas and on the public bad characteristic of pollution.

The foreign country's best response function is

$$e^*_{u^*} \frac{du^*}{dL^*_z} = (R^*_p - e^*_p)\frac{dp}{dL^*_z} + (L^*_z + R^*_{\tau_z})\frac{d\tau_z}{dL^*_z} + (\tau_z - e^*_{u^*}\eta\theta)\frac{dz^*}{dL^*_z} + (\tau_z - e^*_{u^*}\eta\hat{\theta})\frac{dz}{dL^*_z} \tag{3.84}$$

Differentiating Eq.s (3.81a) and (3.82) with respect to L_z we have, respectively,

$$(\beta + \beta^*)\frac{dp}{dL_z} = \left(R_{p\tau_z} + R^*_{p\tau_z}\right)\frac{d\tau_z}{dL_z} \tag{3.85}$$

$$\left(R_{\tau_z\tau_z} + R^*_{\tau_z\tau_z}\right)\frac{d\tau_z}{dL_z} + \left(R_{p\tau_z} + R^*_{p\tau_z}\right)\frac{dp}{dL_z} = -1 \tag{3.86}$$

The above two equations, together, imply

$$\frac{d\tau_z}{dL_z} = -\frac{(\beta + \beta^*)}{(\beta + \beta^*)(R_{\tau_z\tau_z} + R^*_{\tau_z\tau_z}) + (R_{p\tau_z} + R^*_{p\tau_z})^2} \tag{3.87}$$

Since both countries face the same price vectors, if we define $J(p, \tau_z) \equiv R(p, \tau_z) + R^*(p, \tau_z)$, then $J(p, \tau_z)$ is convex in prices. Hence, the denominator in the above equation is negative and $\frac{d\tau_z}{dL_z} < 0$. Furthermore, since, $z^* = -R^*_{\tau_z}$,

$$\frac{dz^*}{dL_z} = -R^*_{\tau_z\tau_z}\frac{d\tau_z}{dL_z} - R^*_{p\tau_z}\frac{dp}{dL_z}$$

المنارة للاستشارات
www.manaraa.com

which, using Eq.s (3.85) and (3.87), implies

$$\frac{dz^*}{dL_z} = \frac{(\beta+\beta^*)R^*_{\tau_z\tau_z} + R^*_{p\tau_z}(R_{p\tau_z} + R^*_{p\tau_z})}{(\beta+\beta^*)(R_{\tau_z\tau_z} + R^*_{\tau_z\tau_z}) + (R_{p\tau_z} + R^*_{p\tau_z})^2} \in (0,1) \tag{3.88}$$

Furthermore, if both countries have the same technology and face the same price vector, then $\frac{dz^*}{dL_z} = \frac{dz}{dL_z} = \frac{1}{2}$.

If the home and foreign countries are identical, then, if $L_z = z^a = z^{a*} = L_z^*$, then $e_p(.) = R_p(.)$ and $\tau_z = e_u\eta\theta$. Evaluating Eq. (3.83) at the autarky solution, $L_z = z^a$, we have

$$\left(e_u\frac{du}{dL_z}\right)_{L_z=z^a} = \left(\tau_z^a - e_u\eta\hat{\theta}\right)\frac{dz^*}{dL_z} \tag{3.89}$$

$(\tau_z^a - e_u\eta\hat{\theta}) > 0$ if the marginal damage from domestic pollution is higher than that from transboundary pollution, i.e., if $\theta > \hat{\theta}$, and Eq. (3.88) $\Rightarrow \frac{dz^*}{dL_z} > 0$; thus, Eq. (3.89) implies (since $e_u > 0$)

$$\left(\frac{du}{dL_z}\right)_{L_z=z^a} > 0 \quad \text{if} \quad \theta > \hat{\theta} \tag{3.90}$$

Hence, when pollution is not a pure global public bad, in the symmetric equilibrium, each country's optimal response is to issue more quotas under free trade as compared to autarky. This leads to a race to the bottom in environmental policy and leaves *both* countries worse off as a result of trade liberalization. Moreover, even if the countries are not identical, by continuity, our results hold if countries are *sufficiently* similar.

However, if pollution is a pure global public bad, i.e., if $\hat{\theta} = \theta$, then Eq. (3.89) implies

$$\left(\frac{du}{dL_z}\right)_{L_z=z^a} = 0 \quad \text{if} \quad \hat{\theta} = \theta \tag{3.91}$$

Hence, if pollution is a pure global public bad, i.e., if $\hat{\theta} = \theta$, then in the symmetric equilibrium, the free trade and autarky equilibrium is the same when countries use internationally tradable quotas to regulate pollution.

3.6.4 Pollution and Welfare

It is straightforward to derive the Pareto efficient tax

$$t_z^e = e_u\eta\theta + e^*_{u*}\eta\hat{\theta} > t_z^a \tag{3.92}$$

المنارة للاستشارات
www.manaraa.com

The optimal free trade pollution tax for the home country, when both countries are identical and use taxes to regulate pollution, is

$$t_z = e_u\eta\theta + \frac{e_u\eta\hat{\theta}(R_{pt_z}R^*_{pt^*_z})}{(\beta+\beta^*)R_{t_zt_z}} < t^a_z \tag{3.93}$$

When identical countries use internationally nontradable quotas to regulate domestic pollution, the pollution tax equivalent of the optimal free trade emission quota is

$$\hat{\tau}_z = e_u\eta\theta = t^a_z \tag{3.94}$$

However, when the pollution quotas are tradable across countries, the pollution tax equivalent of the optimal free trade quota is

$$\tau_z = e_u\eta\theta - e_u(\theta-\hat{\theta})\eta\left[\frac{(\beta+\beta^*)R^*_{\tau_z\tau_z} + R^*_{p\tau_z}(R_{p\tau_z}+R^*_{p\tau_z})}{(\beta+\beta^*)(R_{\tau_z\tau_z}+R^*_{\tau_z\tau_z}) + (R_{p\tau_z}+R^*_{p\tau_z})^2}\right] \tag{3.95}$$

If pollution is a pure global public bad, i.e., $\hat{\theta} = \theta$, then $\tau_z = t^a_z$. However, if the marginal damage from domestic pollution is higher than that from transboundary pollution, i.e., $\theta > \hat{\theta}$, then $\tau_z < t^a_z$. Furthermore, it can be verified that $\tau_z > t_z$ if

$$\theta < \hat{\theta}\left[1 - \frac{(R_{pt_z}R^*_{pt^*_z})}{DR_{t_zt_z}(\beta+\beta^*)}\right]$$

where $D \equiv \left[\frac{(\beta+\beta^*)R^*_{\tau_z\tau_z}+R^*_{p\tau_z}(R_{p\tau_z}+R^*_{p\tau_z})}{(\beta+\beta^*)(R_{\tau_z\tau_z}+R^*_{\tau_z\tau_z})+(R_{p\tau_z}+R^*_{p\tau_z})^2}\right]$. Given our assumption of symmetry and since both countries face the same prices, $D = \frac{1}{2}$, which implies that $\tau_z > t_z$ if

$$\theta < \hat{\theta}\left[1 + \frac{(R_{pt_z})^2}{R_{t_zt_z}(R_{pp}-e_{pp})}\right] \tag{3.96}$$

Hence,

$$\begin{aligned} t^e_z > t^a_z = \hat{\tau}_z &= \tau_z > t_z && \text{if} \quad \frac{\theta}{\hat{\theta}} = 1 \\ t^e_z > t^a_z = \hat{\tau}_z &> \tau_z > t_z && \text{if} \quad 1 < \frac{\theta}{\hat{\theta}} < 1 + \frac{(R_{pt_z})^2}{R_{t_zt_z}(R_{pp}-e_{pp})} \\ t^e_z > t^a_z = \hat{\tau}_z &> t_z > \tau_z && \text{if} \quad \frac{\theta}{\hat{\theta}} > 1 + \frac{(R_{pt_z})^2}{R_{t_zt_z}(R_{pp}-e_{pp})} \end{aligned} \tag{3.97}$$

المنارة للاستشارات

www.manaraa.com

Welfare (W_z) under the different policy instruments can be ranked as follows

$$
\begin{aligned}
W_z^{\text{efficient}} > W_z^{\text{autarky}} = W_z^{\text{quota}} &= W_z^{\text{tradable quota}} > W_z^{\text{tax}} \text{ if } \frac{\theta}{\hat{\theta}} = 1 \\
W_z^{\text{efficient}} > W_z^{\text{autarky}} = W_z^{\text{quota}} &> W_z^{\text{tradable quota}} > W_z^{\text{tax}} \text{ if } 1 < \frac{\theta}{\hat{\theta}} < 1 + \frac{(R_{pt_z})^2}{R_{t_z t_z}(R_{pp} - e_{pp})} \\
W_z^{\text{efficient}} > W_z^{\text{autarky}} = W_z^{\text{quota}} &> W_z^{\text{tax}} > W_z^{\text{tradable quota}} \text{ if } \frac{\theta}{\hat{\theta}} > 1 + \frac{(R_{pt_z})^2}{R_{t_z t_z}(R_{pp} - e_{pp})}
\end{aligned}
$$

We have shown, in this section, that in a more general framework, if pollution and output are not necessarily in one-to-one correspondence, the results that we derived earlier in the chapter still hold.

3.7 Concluding Remarks

We have used a simple model to highlight the effect of trade liberalization in the presence of transboundary pollution. The autarky equilibrium is inefficient because countries do not internalize the transboundary effects of domestic emissions. The Pareto efficient equilibrium requires both countries to internalize the effects of transboundary pollution and is, naturally, welfare improving. The movement from autarky to free trade can be welfare reducing. If countries are identical and environmental taxes are set non-cooperatively, then the transboundary pollution effect, by increasing foreign emissions under trade, reduces the benefits of tighter domestic environmental policy. Although, in equilibrium, there is no trade in our symmetric model, the possibility of trade provides the opportunity to influence world prices and influence foreign production and emissions, thereby leading to a race to the bottom in environmental taxes, which makes *both* countries worse off relative to autarky.

When quotas are the policy instruments, changes in domestic policy do not affect foreign emissions and there is no incentive to distort domestic policy. Even when the quotas are tradable across countries, if pollution is a pure global public bad, then there is no race to the bottom. However, if pollution is not a pure global public bad, then there is a race to the bottom in environmental policy with internationally tradable permits, which, again, makes *both* countries worse off as compared to autarky. Here the lower marginal damage from increased

www.manaraa.com

issue of pollution permits under free trade as compared to autarky is the driving force behind the race to the bottom.

The internationally nontradable quota equilibrium welfare-dominates both the internationally tradable quota equilibrium and the tax equilibrium. The internationally tradable quota equilibrium strictly welfare-dominates (is welfare-dominated by) the tax equilibrium depending on the severity of transboundary pollution and the relative slopes of the demand and supply schedules in the two countries. Pollution is the lowest when internationally nontradable quotas are the policy instruments and the pollution ranking of the internationally tradable quota equilibrium and the tax equilibrium depends on the ratio of transboundary to domestic pollution and the relative slopes of the supply and demand schedules. All these results hold in our generalization of the model. Although we have used identical countries to isolate the role of carbon leakage, it should be clear that, by continuity, our results hold even if countries are not identical, provided they are *sufficiently* similar. We find that internationally nontradable quotas are welfare-superior to taxes. Other factors, such as imperfect competition or imperfect information, might favor price-based policies. Hence, this warrants a more careful analysis of the choice and restriction of policy instruments in the presence of transboundary externalities and non-cooperative policy settings. The importance of the proper choice of policy instruments becomes more crucial the more similar countries are, because certain instruments may result in *both* countries being worse off with trade liberalization, while others do not. An important policy implication is that, when countries negotiate on free trade, it might be beneficial to negotiate on the policy instrument, if not the exact level of the policy instrument, that is used to regulate the domestic externality in each country.

A possible avenue of future research is to allow for imperfect information between countries, and verify if the welfare rankings of policy instruments derived in this chapter hold in a sequential game, where countries try to infer about the preference or technology of each other from their choice of policy instrument.

المنارة للاستشارات

www.manaraa.com

CHAPTER 4. TRADE LIBERALIZATION AND STRATEGIC ENVIRONMENTAL POLICY

4.1 Introduction

In the previous chapter, we analyzed the effect of trade liberalization on domestic environmental policy and welfare when countries set their domestic environmental policies non-cooperatively, in the presence of an international transboundary externality, under free trade. In this chapter we extend the analysis carried out in the previous chapter. This chapter follows the structure of the previous one; however, we explicitly model differences in the production possibility frontiers and preferences between countries which can lead to (potentially welfare improving) trade in equilibrium. We analyze how the choice of the policy instrument used to regulate the domestic externality affects the outcome of trade liberalization.

We employ a two good model of trade between two countries. Production of one of the goods, X, generates pollution as a by-product, that reduces welfare in both countries, but does not affect the production possibility set. In this framework we analyze the effect of a movement from autarky to free trade on environmental policy, pollution and welfare. We find that, although taxes and quotas are equivalent under autarky, this equivalence does not hold in the free trade equilibrium. As in the previous chapter, if countries are identical, there is a race to the bottom when countries use taxes to regulate pollution, but not when the environmental policy instrument is a quota.

When countries are not identical and there is trade in equilibrium, the importer of X lowers its environmental tax under free trade as compared to autarky. As is well known, the standard terms of trade argument implies that a large country should subsidize domestic production of the importable when commercial policies are not available. Furthermore, the transboundary

المنارة للاستشارات
www.manaraa.com

pollution effect, irrespective of the direction of trade, motivates governments to lower the tax on the polluting good to reduce the incidence of transboundary pollution from the other country. Hence, in the importer of X, both the terms of trade effect and the transboundary pollution effect work in the same direction to reduce the environmental tax. In the exporter of the polluting good, the terms of trade effect tends to increase the tax on the polluting good, while the transboundary pollution effect works in the opposite direction. Hence, the exporter of X lowers (increases) its tax on X if the transboundary pollution effect dominates (is dominated by) the terms of trade effect. The welfare effect of trade liberalization depends on whether the welfare gain from the opportunity to trade or the welfare loss due to increased pollution dominates.

When countries use quotas to regulate pollution, then production of the polluting good decreases (increases) in the importer (exporter) of the polluting good, while total (world) production is unchanged as countries move from autarky to free trade. When pollution is a pure global public bad, world pollution rises (declines) if the exporter's pollution intensity is higher (lower) than that of the importer of X.

The rest of the chapter is organized as follows: the next section presents the model. Sections 4.3 and 4.4 look at the autarky and efficient equilibrium, respectively. The free trade equilibrium is presented in Section 4.5 and Section 4.6 analyzes some special cases. Section 4.7 concludes the chapter.

4.2 The Model

Consider a standard two good (X, Y) model of trade between two countries, a home country and a foreign country (denoted by *). Home and foreign production possibility frontiers are, respectively,

$$g(x, y) \geq 0, \quad g(x^*, y^*) \geq 0; \qquad g_i < 0, \quad i = x, y, x^*, y^* \tag{4.1}$$

Assume the following specific functional forms

$$y \leq A - \left(\frac{x^2}{2\gamma} - \frac{\alpha x}{\gamma}\right), \quad y^* \leq A^* - \left(\frac{x^{*2}}{2\gamma} - \frac{\alpha^* x^*}{\gamma}\right) \tag{4.2}$$

المنارة للاستشارات
www.manaraa.com

Emissions are a by-product of the production of X; good Y does not pollute. We assume that production of one unit of X in the home country generates θ units of emissions in the home country and, due to transboundary pollution, $\lambda\theta$ units of emissions in the foreign country. Similarly, production of one unit of X in the foreign country generates θ^* units of emissions in the foreign country and, due to transboundary pollution, $\lambda\theta^*$ units of emissions in the home country. Thus, total pollution in the home and foreign countries are, respectively,

$$z = \theta x + \lambda\theta^* x^*, \quad z^* = \lambda\theta x + \theta^* x^*; \quad \lambda \in (0, 1] \tag{4.3}$$

When $\lambda < 1$, domestic pollution causes a higher marginal damage than transboundary pollution, while pollution is a pure global public bad if $\lambda = 1$.

Let $c_x(c_x^*)$ and $c_y(c_y^*)$ denote consumption of X and Y in the home (foreign) country. Preferences of the representative agents in the home and foreign countries are given by the following utility functions

$$U(c_x, c_y, z) = c_y + \frac{\beta}{\delta}c_x - \frac{c_x^2}{2\delta} - \eta z, \quad U(c_x^*, c_y^*, z^*) = c_y^* + \frac{\beta^*}{\delta}c_x^* - \frac{c_x^{*2}}{2\delta} - \eta^* z^*; \qquad \eta, \eta^* > 0 \tag{4.4}$$

Assume that good Y is the numeraire good; hence, $p_y \equiv 1$. Given the above production and preference structure, demand and supply functions for X in the home and foreign countries are, respectively,

$$c_x = \beta - \delta p; \qquad c_x^* = \beta^* - \delta p^* \tag{4.5}$$

$$x = \alpha + \gamma p^f; \qquad x^* = \alpha^* + \gamma p^{f*} \tag{4.6}$$

where, p, $p^f(= p - t)$, and t are the home country's consumer price of X, producer price of X and production tax on X, respectively. Similarly, p^*, $p^{f*}(= p^* - t^*)$, and t^* are the foreign country's consumer price of X, producer price of X and production tax on X, respectively. The import demand functions of the home country and foreign country are, respectively,

$$M_x = (\beta - \alpha) - (\gamma + \delta)p + \gamma t; \qquad M_x^* = (\beta^* - \alpha^*) - (\gamma + \delta)p^* + \gamma t^* \tag{4.7}$$

The inverse demand and supply functions are, respectively,

$$p = \frac{\beta - c_x}{\delta}; \qquad p^* = \frac{\beta^* - c_x^*}{\delta} \tag{4.8}$$

المنارة للاستشارات
www.manaraa.com

$$p^f = \frac{x-\alpha}{\gamma}; \qquad p^{f*} = \frac{x^* - \alpha^*}{\gamma} \tag{4.9}$$

Given our specification of preferences and technology, assuming that there are no border taxes (tariffs), the home country's welfare can be written in terms of the standard partial equilibrium welfare measure as the sum of consumer surplus, producer surplus and tax revenue less the damage from pollution:

$$W = A + \int_0^{c_x} \left(\frac{\beta - c_x}{\delta}\right) dc_x - pc_x + p^f x - \int_0^{x} \left(\frac{x-\alpha}{\gamma}\right) dx + tx - \eta z$$

i.e.,

$$W = A + \left(\frac{\beta}{\delta} c_x - \frac{c_x^2}{2\delta}\right) - pM_x - \left(\frac{x^2}{2\gamma} - \frac{\alpha x}{\gamma}\right) - \eta\left(\theta x + \lambda \theta^* x^*\right) \tag{4.10}$$

Similarly, foreign welfare is given by

$$W^* = A^* + \left(\frac{\beta^*}{\delta} c_x^* - \frac{c_x^{*2}}{2\delta}\right) - p^* M_x^* - \left(\frac{x^{*2}}{2\gamma} - \frac{\alpha^* x^*}{\gamma}\right) - \eta^*\left(\theta^* x^* + \lambda \theta x\right) \tag{4.11}$$

4.3 Autarky

We first solve the domestic social planner's problem. In autarky, $M_x = 0$, hence the autarkic consumer price of X in the home country is

$$p^a = \frac{\beta - \alpha}{\gamma + \delta} + \frac{\gamma}{\gamma + \delta} t \tag{4.12}$$

The benevolent home government chooses its domestic production tax, t, to maximize its own citizen's welfare (Eq. (4.10)), which yields the following optimality condition (since $M_x^a = 0$, $\frac{dp^a}{dt} = \frac{\gamma}{\gamma+\delta}$ and $\frac{dp^{a*}}{dt} = 0$)

$$\frac{dW^a}{dt} = (t - \eta\theta)\frac{dx}{dt}$$

Thus, the home country's optimal autarky production tax is (since $\frac{dx}{dt} < 0$)

$$t^a = \eta\theta \tag{4.13}$$

Similarly, the foreign optimal autarky production tax is

$$t^{a*} = \eta^* \theta^* \tag{4.14}$$

المنارة للاستشارات
www.manaraa.com

The equivalent autarky tax on emissions is

$$t_z^a = \eta; \qquad t_z^{a*} = \eta^*$$

i.e., a tax equal to the domestic marginal damage from pollution. Note that this autarky solution is inefficient from the global perspective as governments do not internalize the transboundary effect of their emissions.

The maximized autarky welfare levels in the home and foreign countries are, respectively,

$$W = A + \frac{(\gamma\beta + \alpha\delta - \gamma\delta\eta\theta)^2}{2\gamma\delta(\gamma+\delta)} - \frac{\lambda\eta\theta^*(\gamma\beta^* + \alpha^*\delta - \gamma\delta\eta^*\theta^*)}{(\gamma+\delta)} \tag{4.15}$$

$$W^* = A^* + \frac{(\gamma\beta^* + \alpha^*\alpha^*\delta - \gamma\delta\eta^*\theta^*)^2}{2\gamma\delta(\gamma+\delta)} - \frac{\lambda\eta^*\theta(\gamma\beta + \alpha\delta - \gamma\delta\eta\theta)}{(\gamma+\delta)} \tag{4.16}$$

The difference between the autarky (consumer) prices in the home and foreign countries is

$$p^a - p^{a*} = \frac{(\beta - \alpha) - (\beta^* - \alpha^*)}{\gamma + \delta} + \frac{\gamma(\eta\theta - \eta^*\theta^*)}{\gamma + \delta} \tag{4.17}$$

We define the natural pattern of trade as that determined by the autarkic prices, i.e., it is the direction of trade that would have prevailed if both countries retained their autarkic environmental policies. Hence, the natural pattern of trade is determined by the sign of the following expression

$$(\beta - \alpha) - (\beta^* - \alpha^*) + \gamma(\eta\theta - \eta^*\theta^*)$$

If $(\beta - \alpha) - (\beta^* - \alpha^*) + \gamma(\eta\theta - \eta^*\theta^*) > (<)\ 0$, then the home country is the natural importer (exporter) of X.

4.4 Efficient Equilibrium

We obtain the Pareto efficient allocations by solving a social planner's problem that maximizes the welfare of the home country subject to meeting a certain utility target for the foreign country. Naturally, the social planner accounts for the domestic and transboundary externalities. It is straightforward to verify that the Pareto efficient taxes on the production of the polluting good, X, in the home and foreign countries are, respectively,

$$t^e = (\eta + \lambda\eta^*)\theta; \qquad t^{e*} = (\eta^* + \lambda\eta)\theta^* \tag{4.18}$$

المنارة للاستشارات
www.manaraa.com

The Pareto efficient emission taxes in the home and foreign countries are, respectively,

$$t_z^e = (\eta + \lambda\eta^*); \qquad t_z^{e*} = (\eta^* + \lambda\eta) \tag{4.19}$$

and the price of X is

$$p^e = \frac{\beta - \alpha}{\gamma + \delta} + \frac{\gamma}{\gamma + \delta}(\eta + \lambda\eta^*)\theta, \quad p^{e*} = \frac{\beta^* - \alpha^*}{\gamma + \delta} + \frac{\gamma}{\gamma + \delta}(\eta^* + \lambda\eta)\theta^* \tag{4.20}$$

Thus, efficiency need not require equalization of environmental taxes across countries, but it does require that both countries internalize the domestic and transboundary effects of emissions. However, if pollution is a pure global public bad, i.e., if $\lambda = 1$, then the Pareto efficient tax on pollution is, in fact, equalized across countries.

The difference in the efficient (consumer) prices of X between the two countries,

$$p^e - p^{e*} = \frac{(\beta - \alpha) - (\beta^* - \alpha^*) + \gamma((\eta + \lambda\eta^*)\theta - (\eta^* + \lambda\eta)\theta^*)}{(\gamma + \delta)} \tag{4.21}$$

determines the efficient pattern of trade. In particular, if $(\beta - \alpha) - (\beta^* - \alpha^*) + \gamma((\eta + \lambda\eta^*)\theta - (\eta^* + \lambda\eta)\theta^*) > (<) 0$, then the home country imports (exports) X in the efficient equilibrium.

4.5 Free Trade

In this section we analyze the effects of a movement from autarky to free trade and how the choice of the policy instrument governs these effects. We consider each country's optimal non-cooperative environmental policy, given that they have committed to free trade and that they act simultaneously. We consider two cases: i) governments regulate emissions using a tax on domestic emissions (equivalent to a tax on the production of X), and ii) emission (or production) quotas are used to regulate pollution.

4.5.1 Taxes

The only policy instrument available to each country is a tax on emissions. Given the one-to-one correspondence between output and emissions, this is equivalent to a tax on the production of X, denoted by t and t^*, and we carry out our analysis using equivalent production

المنارة للاستشارات

www.manaraa.com

policies. Let p be the (world) consumer price of X. The balance of trade condition, $M_x + M_x^* = 0$, implies

$$p = \frac{(\beta - \alpha) + (\beta^* - \alpha^*)}{2(\gamma + \delta)} + \frac{\gamma(t + t^*)}{2(\gamma + \delta)} \tag{4.22}$$

The home country's welfare is given by Eq. (4.10). Differentiating Eq. (4.10) with respect to t, we get the home country's best response function as a function of the foreign country's tax

$$\frac{dW}{dt} = (x - c_x)\frac{dp}{dt} + (t - \eta\theta)\frac{dx}{dt} - \lambda\eta\theta^*\frac{dx^*}{dt} \tag{4.23}$$

The first term, the terms of trade effect, depends on whether the country is a net importer of X. The second term is the effect of changes in t on domestic pollution: as t increases, domestic emissions decline. An increase in the domestic environmental tax reduces domestic production of the polluting good resulting, under trade, in an increase in p, which increases foreign production and emissions. Thus, the last term reflects the transboundary pollution effect.

Similarly, the foreign country's best response function as a function of the home country's tax is

$$\frac{dW^*}{dt^*} = (x^* - c_x^*)\frac{dp}{dt^*} + (t^* - \eta^*\theta^*)\frac{dx^*}{dt^*} - \lambda\eta^*\theta\frac{dx}{dt^*} \tag{4.24}$$

Since $\frac{dx}{dt} = \gamma\left(\frac{dp}{dt} - 1\right)$, $\frac{dx^*}{dt} = \gamma\frac{dp}{dt}$ and $\frac{dp}{dt} = \frac{\gamma}{2(\gamma+\delta)}$, the home country's best response function is

$$t = \eta\theta - \frac{\gamma\eta\theta + ((\beta - \alpha) - (\beta^* - \alpha^*)) + 2\lambda\gamma\eta\theta^* - \gamma t^*}{(3\gamma + 4\delta)} \tag{4.25}$$

Similarly, the foreign country's best response function is

$$t^* = \eta^*\theta^* - \frac{\gamma\eta^*\theta^* - ((\beta - \alpha) - (\beta^* - \alpha^*)) + 2\lambda\gamma\eta^*\theta - \gamma t}{(3\gamma + 4\delta)} \tag{4.26}$$

Solving the home and foreign best response functions, Eq.s (4.25) and (4.26), simultaneously we have

$$t = \eta\theta - \frac{((\beta - \alpha) - (\beta^* - \alpha^*) + \gamma(\eta\theta - \eta^*\theta^*))}{4(\gamma + \delta)} - \frac{\lambda\gamma\left((3\gamma + 4\delta)\eta\theta^* + \gamma\eta^*\theta\right)}{4(\gamma + \delta)(\gamma + 2\delta)} \tag{4.27}$$

and,

$$t^* = \eta^*\theta^* + \frac{((\beta - \alpha) - (\beta^* - \alpha^*) + \gamma(\eta\theta - \eta^*\theta^*))}{4(\gamma + \delta)} - \frac{\lambda\gamma\left((3\gamma + 4\delta)\eta^*\theta + \gamma\eta\theta^*\right)}{4(\gamma + \delta)(\gamma + 2\delta)} \tag{4.28}$$

المنارة للاستشارات
www.manaraa.com

In the absence of a pollution externality, the second term, the terms of trade effect, alone determines the output tax. If $\eta = \eta^* = 0$ and $(\beta - \alpha) > (\beta^* - \alpha^*)$, i.e., if the home country is a natural importer of X, then the home country's optimal free trade output tax is negative. Here, the standard terms of trade argument applies, whereby, in the absence of commercial policies, it is optimal for a large country to subsidize domestic production of the importable. Similarly, the foreign country's optimal free trade output tax is positive. However, in the presence of a pollution externality, the last term, the transboundary pollution effect, tends to reduce the domestic environmental tax irrespective of the pattern of trade. Its magnitude depends on the severity of transboundary pollution: as λ increases, the transboundary pollution effect increases, and this tends to lower the domestic environmental tax. Hence, the free trade output tax is decreasing in λ in both countries. Furthermore, note that the sum of the taxes in the two countries, $t + t^* = \eta\theta + \eta^*\theta^* - \frac{\lambda\gamma(\eta\theta^* + \eta^*\theta)}{(\gamma + 2\delta)}$, is independent of α, β, α^* and β^*.

Proposition 10. *If there is no motive for trade between the countries, i.e., if* $(\beta - \alpha) + \gamma\eta\theta = (\beta^* - \alpha^*) + \gamma\eta^*\theta^*$, *such that the autarky relative (consumer) price is the same in both countries, and countries set domestic environmental taxes non-cooperatively, then both countries lower environmental taxes under free trade as compared to autarky.*

The above proposition reflects the race to the bottom result of Chapter 3.

The transboundary pollution effect always tends to lower the tax on X. However, in the presence of a motive for trade, if the home country is a natural importer of X, i.e., if $(\beta - \alpha) + \gamma\eta\theta > (\beta^* - \alpha^*) + \gamma\eta^*\theta^*$, the terms of trade effect tends to reduce the importer's environmental tax. Thus, the terms of trade effect and the transboundary pollution effect, reinforce each other and $t < t^a$. The change in the environmental tax in the home country due to trade liberalization is

$$t - t^a = -\frac{((\beta - \alpha) - (\beta^* - \alpha^*) + \gamma(\eta\theta - \eta^*\theta^*))}{4(\gamma + \delta)} - \frac{\lambda\gamma\left((3\gamma + 4\delta)\eta\theta^* + \gamma\eta^*\theta\right)}{4(\gamma + \delta)(\gamma + 2\delta)} < 0 \qquad (4.29)$$

The terms of trade effect tends to increase the environmental tax in the foreign country (exporter of X); thus, the transboundary pollution effect and the terms of trade effect work in opposite directions for an exporter of X. The change in the foreign country's output tax due

المنارة للاستشارات
www.manaraa.com

to a movement from autarky to free trade is

$$t^* - t^{a*} = \frac{((\beta-\alpha)-(\beta^*-\alpha^*)+\gamma(\eta\theta-\eta^*\theta^*))}{4(\gamma+\delta)} - \frac{\lambda\gamma\left((3\gamma+4\delta)\eta^*\theta+\gamma\eta\theta^*\right)}{4(\gamma+\delta)(\gamma+2\delta)} \tag{4.30}$$

Hence $t^* < t^{a*}$ if, and only if,

$$((\beta-\alpha)-(\beta^*-\alpha^*)+\gamma(\eta\theta-\eta^*\theta^*)) < \frac{\lambda\gamma\left((3\gamma+4\delta)\eta^*\theta+\gamma\eta\theta^*\right)}{(\gamma+2\delta)} \tag{4.31}$$

Again, as the severity of transboundary pollution, λ, increases, it tends to make the transboundary pollution effect stronger, which, in turn, tends to make it more likely that the exporter of the polluting good also reduces its domestic environmental tax under free trade relative to autarky. We summarize these results in the following proposition

Proposition 11. *If countries choose their domestic environmental taxes non-cooperatively, then the natural importer of X unambiguously lowers its environmental tax under free trade as compared to autarky, while in the natural exporter of X, the environmental tax increases (decreases) if the terms of trade effect dominates (is dominated by) the transboundary pollution effect.*

Using Eq.s (4.22), (4.27) and (4.28), the free trade (consumer) price of X can be derived as

$$p = \frac{(\beta-\alpha)+(\beta^*-\alpha^*)}{2(\gamma+\delta)} + \frac{\gamma}{2(\gamma+\delta)}\left(\eta\theta+\eta^*\theta^* - \frac{\lambda\gamma(\eta\theta^*+\eta^*\theta)}{(\gamma+2\delta)}\right) \tag{4.32}$$

The change in the home country's production of X is

$$\Delta x = x - x^a = -\frac{\gamma\left((\beta-\alpha)-(\beta^*-\alpha^*)+\gamma(\eta\theta-\eta^*\theta^*)\right)}{4(\gamma+\delta)} - \frac{\lambda\gamma^2\left(\gamma\eta^*\theta-(\gamma+4\delta)\eta\theta^*\right)}{4(\gamma+\delta)(\gamma+2\delta)} \tag{4.33}$$

where, x^a and x are the home country's supply of X in autarky and free trade, respectively. If there is no motive for trade, i.e., if $(\beta-\alpha)+\gamma\eta\theta = (\beta^*-\alpha^*)+\gamma\eta^*\theta^*$, the home country's production of X increases due to trade liberalization if $(\frac{\gamma}{\delta}+4)\frac{\eta}{\eta^*}\frac{\theta^*}{\theta} > \frac{\gamma}{\delta}$. However, if there is a motive for trade, the home country's production of X increases if $\eta\theta^* > \frac{\gamma\eta^*\theta}{(\gamma+4\delta)} + \frac{(\gamma+2\delta)((\beta-\alpha)-(\beta^*-\alpha^*)+\gamma(\eta\theta-\eta^*\theta^*))}{\lambda\gamma(\gamma+4\delta)}$. Similarly, the change in the foreign production of X is

$$\Delta x^* = x^* - x^{a*} = \frac{\gamma\left((\beta-\alpha)-(\beta^*-\alpha^*)+\gamma(\eta\theta-\eta^*\theta^*)\right)}{4(\gamma+\delta)} + \frac{\lambda\gamma^2\left((\gamma+4\delta)\eta^*\theta-\gamma\eta\theta^*\right)}{4(\gamma+\delta)(\gamma+2\delta)} \tag{4.34}$$

المنارة للاستشارات
www.manaraa.com

In the absence of a motive for trade, the foreign country's production of X increases if $(\frac{\gamma}{\delta}+4) > \frac{\gamma}{\delta}\frac{\eta}{\eta^*}\frac{\theta^*}{\theta}$. But, if the foreign country is a natural exporter of X, foreign production of X increases due to trade liberalization if $(\gamma+2\delta)\left((\beta-\alpha)-(\beta^*-\alpha^*)+\gamma(\eta\theta-\eta^*\theta^*)\right)+\lambda\gamma(\gamma+4\delta)\eta^*\theta > \lambda\gamma^2\eta\theta^*$. The change in the total world production of X is

$$\Delta x^w = \Delta x + \Delta x^* = \frac{\lambda\gamma^2\delta(\eta\theta^*+\eta^*\theta)}{(\gamma+\delta)(\gamma+2\delta)} > 0 \tag{4.35}$$

Hence, total world production of X is independent of α, β, α^* and β^*, and unambiguously increases due to a movement from autarky to free trade when countries use taxes to regulate domestic pollution.

The increase in total pollution in the home country due to trade liberalization is $\Delta z = z - z^a = \theta(x-x^a)+\lambda\theta^*(x^*-x^{a*})$:

$$\begin{aligned}\Delta z \quad &= \quad \frac{\gamma(\lambda\theta^*-\theta)\left((\beta-\alpha)-(\beta^*-\alpha^*)+\gamma(\eta\theta-\eta^*\theta^*)\right)}{4(\gamma+\delta)} \\ &+ \frac{\lambda\gamma^2\left((\gamma+4\delta)(\eta+\lambda\eta^*)\theta\theta^*-\lambda\gamma(\eta\theta^{*2}+\eta^*\theta^2)\right)}{4(\gamma+\delta)(\gamma+2\delta)}\end{aligned} \tag{4.36}$$

Whether total pollution in the home country increases as a result of trade liberalization depends on whether the terms of trade effect or the transboundary pollution effect dominates.

The increase in total pollution in the foreign country due to trade liberalization is $\Delta z^* = z^* - z^{a*} = \theta^*(x^*-x^{a*})+\lambda\theta(x-x^a)$:

$$\begin{aligned}\Delta z^* \quad &= \quad \frac{\gamma(\theta^*-\lambda\theta)\left((\beta-\alpha)-(\beta^*-\alpha^*)+\gamma(\eta\theta-\eta^*\theta^*)\right)}{4(\gamma+\delta)} \\ &+ \frac{\lambda\gamma^2\left((\gamma+4\delta)(\eta^*+\lambda\eta)\theta\theta^*-\lambda\gamma(\eta^*\theta^2+\eta\theta^{*2})\right)}{4(\gamma+\delta)(\gamma+2\delta)}\end{aligned} \tag{4.37}$$

When pollution is a pure global public bad, i.e., if $\lambda = 1$, the change in pollution due to a movement from autarky to free trade is $\Delta z^w = \Delta z = \Delta z^* = \theta\Delta x + \theta^*\Delta x^*$,

$$\begin{aligned}\Delta z^w \quad &= \quad \frac{\gamma(\theta^*-\theta)\left((\beta-\alpha)-(\beta^*-\alpha^*)+\gamma(\eta\theta-\eta^*\theta^*)\right)}{4(\gamma+\delta)} \\ &+ \frac{\gamma^2\left[((\gamma+4\delta)\theta^*-\gamma\theta)\eta^*\theta+((\gamma+4\delta)\theta-\gamma\theta^*)\eta\theta^*\right]}{4(\gamma+\delta)(\gamma+2\delta)}\end{aligned} \tag{4.38}$$

Furthermore, if $\theta = \theta^*$, then

$$\Delta z^w = \frac{\gamma^2\delta(\eta+\eta^*)\theta^2}{(\gamma+\delta)(\gamma+2\delta)} > 0$$

and total world pollution increases as a result of trade liberalization.

www.manaraa.com

Proposition 12. *When countries set environmental taxes non-cooperatively, but otherwise pursue free trade, if pollution is a pure global public bad, i.e., if $\lambda = 1$, and if $\theta^* = \theta$, then pollution unambiguously increases under free trade as compared to autarky.*

The change in the home country's welfare due to a movement from autarky to free trade is $\Delta W = W - W^a$, where W and W^a are welfare (as measured by Eq. (4.10)) under free trade and autarky, respectively,

$$\begin{aligned}\Delta W \;=\;& \frac{(3\gamma+4\delta)(\gamma+2\delta)^2\left((\beta-\alpha)-(\beta^*-\alpha^*)+\gamma(\eta\theta-\eta^*\theta^*)\right)^2}{32(\gamma+\delta)^2(\gamma+2\delta)^2}\\ &+\frac{2\lambda\gamma(\gamma+2\delta)\left((\beta-\alpha)-(\beta^*-\alpha^*)+\gamma(\eta\theta-\eta^*\theta^*)\right)\left(\gamma(3\gamma+4\delta)\eta^*\theta\right)}{32(\gamma+\delta)^2(\gamma+2\delta)^2}\\ &-\frac{2\lambda\gamma(\gamma+2\delta)\left((\beta-\alpha)-(\beta^*-\alpha^*)+\gamma(\eta\theta-\eta^*\theta^*)\right)\left((3\gamma^2+12\gamma\delta+8\delta^2)\eta\theta^*\right)}{32(\gamma+\delta)^2(\gamma+2\delta)^2}\\ &+\frac{\lambda^2\gamma^2(3\gamma+4\delta)\left(\gamma^2\eta^2\theta^{*2}-2(\gamma^2+8\gamma\delta+8\delta^2)\eta\eta^*\theta\theta^*+\gamma^2\eta^{*2}\theta^2\right)}{32(\gamma+\delta)^2(\gamma+2\delta)^2} \qquad (4.39)\end{aligned}$$

Similarly, the change in foreign welfare resulting from trade liberalization is

$$\begin{aligned}\Delta W^* \;=\;& \frac{(3\gamma+4\delta)(\gamma+2\delta)^2\left((\beta-\alpha)-(\beta^*-\alpha^*)+\gamma(\eta\theta-\eta^*\theta^*)\right)^2}{32(\gamma+\delta)^2(\gamma+2\delta)^2}\\ &-\frac{2\lambda\gamma(\gamma+2\delta)\left((\beta-\alpha)-(\beta^*-\alpha^*)+\gamma(\eta\theta-\eta^*\theta^*)\right)\left(\gamma(3\gamma+4\delta)\eta\theta^*\right)}{32(\gamma+\delta)^2(\gamma+2\delta)^2}\\ &+\frac{2\lambda\gamma(\gamma+2\delta)\left((\beta-\alpha)-(\beta^*-\alpha^*)+\gamma(\eta\theta-\eta^*\theta^*)\right)\left((3\gamma^2+12\gamma\delta+8\delta^2)\eta^*\theta\right)}{32(\gamma+\delta)^2(\gamma+2\delta)^2}\\ &+\frac{\lambda^2\gamma^2(3\gamma+4\delta)\left(\gamma^2\eta^2\theta^{*2}-2(\gamma^2+8\gamma\delta+8\delta^2)\eta\eta^*\theta\theta^*+\gamma^2\eta^{*2}\theta^2\right)}{32(\gamma+\delta)^2(\gamma+2\delta)^2} \qquad (4.40)\end{aligned}$$

Note that, in the absence of transboundary pollution, i.e., if $\lambda = 0$, both countries are unambiguously better-off under free trade relative to autarky, if there is a motive for trade.

Using Eq.s (4.39) and (4.40), we can find the change in aggregate (world) welfare [1], ΔW^w, as the sum of ΔW and ΔW^*

$$\begin{aligned}\Delta W^w \;=\;& \frac{(3\gamma+4\delta)(\gamma+2\delta)^2\left((\beta-\alpha)-(\beta^*-\alpha^*)+\gamma(\eta\theta-\eta^*\theta^*)\right)^2}{16(\gamma+\delta)^2(\gamma+2\delta)^2}\\ &+\frac{2\lambda\gamma(\gamma+2\delta)(3\gamma+2\delta)\left((\beta-\alpha)-(\beta^*-\alpha^*)+\gamma(\eta\theta-\eta^*\theta^*)\right)\left(\eta^*\theta-\eta\theta^*\right)}{16(\gamma+\delta)^2(\gamma+2\delta)^2}\\ &+\frac{\lambda^2\gamma^2(3\gamma+4\delta)\left(\gamma^2\eta^2\theta^{*2}-2(\gamma^2+8\gamma\delta+8\delta^2)\eta\eta^*\theta\theta^*+\gamma^2\eta^{*2}\theta^2\right)}{16(\gamma+\delta)^2(\gamma+2\delta)^2} \qquad (4.41)\end{aligned}$$

[1] Note that our assumption of quasilinear preferences allows us to add the changes in welfare of the two countries to determine the change in aggregate world welfare.

المنارة للاستشارات
www.manaraa.com

Note that if there is no motive for trade, i.e., if $(\beta-\alpha)-(\beta^*-\alpha^*)+\gamma(\eta\theta-\eta^*\theta^*)=0$, then both countries gain (lose) due to trade liberalization if $\gamma^2(\eta\theta^*-\eta^*\theta)^2 > (<) 16\delta(\gamma+\delta)\eta\eta^*\theta\theta^*$, i.e, if $\frac{(\frac{\eta}{\eta^*}\frac{\theta^*}{\theta}-1)^2}{\frac{\eta}{\eta^*}\frac{\theta^*}{\theta}} > (<) \frac{16(\frac{\gamma}{\delta}+1)}{(\frac{\gamma}{\delta})^2}$.

Proposition 13. *If countries set domestic environmental taxes non-cooperatively, but pursue free trade,*

1. *if there is a motive for trade, then, in the absence of transboundary pollution, both countries are better-off under free trade as compared to autarky;*
2. *if there is a motive for trade, in the presence of transboundary pollution, there is an ambiguous welfare effect of trade liberalization;*
3. *if there is no motive for trade, such that the autarky relative price is the same in both countries, and there is transboundary pollution, then both countries gain (lose) as a result of a movement from autarky to free trade if* $\frac{(\frac{\eta}{\eta^*}\frac{\theta^*}{\theta}-1)^2}{\frac{\eta}{\eta^*}\frac{\theta^*}{\theta}} > (<) \frac{16(\frac{\gamma}{\delta}+1)}{(\frac{\gamma}{\delta})^2}$.

4.5.2 Quotas

Now consider the case when both governments use command and control policies, such as upper bounds on emissions (or output), instead of taxes, to regulate pollution. Hence, $x \leq L$ and $x^* \leq L^*$, where L and L^* are the production quotas in the home and foreign countries, respectively. Governments simultaneously and non-cooperatively choose their quota levels to maximize welfare. Define the (shadow) value of a quota in the home and foreign countries as $\hat{\tau} \equiv p - p^f$ and $\hat{\tau}^* \equiv p - p^{f*}$, respectively, where p^f (p^{f*}) is the producer price of X in the home (foreign) country. If the quotas are auctioned off or traded domestically then $\hat{\tau}$ and $\hat{\tau}^*$ are the market prices of the quotas in the home and foreign countries, respectively. We assume that quotas in both countries bind, hence $\hat{\tau}, \hat{\tau}^* > 0$. Differentiating Eq. (4.10) with respect to L gives the home country's best response function as a function of the foreign country's quota

$$\frac{dW}{dL} = (x - c_x)\frac{dp}{dL} + (\hat{\tau} - \eta\theta)\frac{dx}{dL} - \lambda\eta\theta^*\frac{dx^*}{dL} \tag{4.42}$$

The first and second terms are the terms of trade and domestic pollution effects, respectively, while the last term is the transboundary pollution effect. The terms of trade effect depends

المنارة للاستشارات
www.manaraa.com

on whether the polluting good is an import of the home country. Issuing an additional quota, given that the quota binds, increases domestic production and domestic emissions. If foreign production changes following changes in domestic quotas, then it affects domestic welfare via a change in the home country's incidence of transboundary pollution.

The foreign country's best response function as a function of the home country's quota is

$$\frac{dW^*}{dL^*} = (x^* - c_x^*)\frac{dp}{dL^*} + (\hat{\tau}^* - \eta^*\theta^*)\frac{dx^*}{dL^*} - \lambda\eta^*\theta\frac{dx}{dL^*} \tag{4.43}$$

Eq.s (4.42) and (4.43) can be solved for the optimal autarky production quotas. In autarky domestic consumption equals domestic production and the quota binds, i.e., $c_x = x = L$, and foreign output is independent of domestic policy, i.e., $\frac{dx^*}{dL} = 0$. Hence, Eq. (4.42) implies that the production tax equivalent of the optimal autarky production quota for the home country is

$$\hat{\tau}^a = \eta\theta \tag{4.44}$$

Similarly, the foreign production tax equivalent of the optimal autarky production quota is

$$\hat{\tau}^{a*} = \eta^*\theta^* \tag{4.45}$$

Comparing Eq.s (4.13), (4.14), (4.44) and (4.45), it can be seen that, under autarky, taxes and quotas are equivalent.

The optimal autarky quota levels in the home and foreign countries are, respectively,

$$L^a = \frac{\gamma\beta + \alpha\delta}{\gamma + \delta} - \frac{\gamma\delta}{\gamma + \delta}\eta\theta, \quad L^{a*} = \frac{\gamma\beta^* + \alpha^*\delta}{\gamma + \delta} - \frac{\gamma\delta}{\gamma + \delta}\eta^*\theta^* \tag{4.46}$$

Now consider each country's optimal non-cooperative environmental policy, given a commitment to free trade. The balance of trade condition, $M_x + M_x^* = 0$, implies that the free trade world (consumer) price of X, in terms of the quota levels in the two countries, is

$$p = \frac{\beta + \beta^*}{2\delta} - \frac{L + L^*}{2\delta} \tag{4.47}$$

Since quotas in both countries bind, $x = L$, $x^* = L^*$, $\frac{dx^*}{dL} = 0$ and $\frac{dx}{dL^*} = 0$, Eq.s (4.42) and (4.43) imply, respectively,

$$\left(\frac{3}{4\delta} + \frac{1}{\gamma}\right)L = \frac{(3\beta + \beta^*)}{4\delta} + \frac{\alpha}{\gamma} - \eta\theta - \frac{L^*}{4\delta} \tag{4.48}$$

المنارة للاستشارات
www.manaraa.com

$$\left(\frac{3}{4\delta}+\frac{1}{\gamma}\right)L^* = \frac{(3\beta^*+\beta)}{4\delta}+\frac{\alpha^*}{\gamma}-\eta^*\theta^*-\frac{L}{4\delta} \tag{4.49}$$

Solving Eq.s (4.48) and (4.49) simultaneously gives the non-cooperative free trade home and foreign quota levels[2]

$$L = \frac{(2\gamma+3\delta)\gamma\beta+(3\gamma+4\delta)\alpha\delta}{2(\gamma+\delta)(\gamma+2\delta)}+\frac{\gamma\delta(\beta^*-\alpha^*)}{2(\gamma+\delta)(\gamma+2\delta)}-\frac{\gamma\delta\left((3\gamma+4\delta)\eta\theta-\gamma\eta^*\theta^*\right)}{2(\gamma+\delta)(\gamma+2\delta)} \tag{4.50}$$

$$L^* = \frac{(2\gamma+3\delta)\gamma\beta^*+(3\gamma+4\delta)\alpha^*\delta}{2(\gamma+\delta)(\gamma+2\delta)}+\frac{\gamma\delta(\beta-\alpha)}{2(\gamma+\delta)(\gamma+2\delta)}-\frac{\gamma\delta\left((3\gamma+4\delta)\eta^*\theta^*-\gamma\eta\theta\right)}{2(\gamma+\delta)(\gamma+2\delta)} \tag{4.51}$$

Using Eq.s (4.46), (4.50) and (4.51), we can find the change in the quota levels in the two countries as a result of a movement from autarky to free trade. Given that the quotas bind in both countries, this is also the change in the production of X due to trade liberalization

$$\Delta x = x - x^a = L - L^a = -\frac{\gamma\delta\left((\beta-\alpha)-(\beta^*-\alpha^*)+\gamma(\eta\theta-\eta^*\theta^*)\right)}{2(\gamma+\delta)(\gamma+2\delta)} \tag{4.52}$$

$$\Delta x^* = x^* - x^{a*} = L^* - L^{a*} = \frac{\gamma\delta\left((\beta-\alpha)-(\beta^*-\alpha^*)+\gamma(\eta\theta-\eta^*\theta^*)\right)}{2(\gamma+\delta)(\gamma+2\delta)} \tag{4.53}$$

The change in the world production of X is

$$\Delta x^w = \Delta x + \Delta x^* = 0 \tag{4.54}$$

Proposition 14. *If there is no motive for trade between the countries, i.e., if* $(\beta-\alpha)+\gamma\eta\theta = (\beta^*-\alpha^*)+\gamma\eta^*\theta^*$*, such that the autarky relative (consumer) price is the same in both countries, and countries set pollution (or production) quotas non-cooperatively, but otherwise pursue free trade, then the autarky and free trade equilibrium are the same, i.e., countries do not change their quota levels due to trade liberalization.*

However, if there is motive for trade between the countries, i.e., if $(\beta-\alpha)+\gamma\eta\theta \neq (\beta^*-\alpha^*)+\gamma\eta^*\theta^*$, then the effect of trade liberalization on production depends on the natural trade pattern. If the home country is a natural importer of X, i.e., if $(\beta-\alpha)+\gamma\eta\theta > (\beta^*-\alpha^*)+\gamma\eta^*\theta^*$, then $\Delta x < 0$ and $\Delta x^* > 0$.

Proposition 15. *If countries set pollution (or production) quotas non-cooperatively, but otherwise pursue free trade, then production (quota level) declines in the natural importer of the*

[2] Note that the home welfare function is strictly concave in L ($\frac{d^2W}{dL^2} = -(\frac{1}{\gamma}+\frac{3}{4\delta})$).

المنارة للاستشارات
www.manaraa.com

polluting good, and it increases in the natural exporter of the polluting good, while total world production is unchanged as a result of a movement from autarky to free trade.

The change in total pollution in the home country due to trade liberalization is $\Delta z = \theta\Delta L + \lambda\theta^*\Delta L^*$:

$$\Delta z = (\lambda\theta^* - \theta)\,\frac{\gamma\delta\left((\beta-\alpha)-(\beta^*-\alpha^*)+\gamma(\eta\theta-\eta^*\theta^*)\right)}{2(\gamma+\delta)(\gamma+2\delta)} \tag{4.55}$$

Similarly, the change in foreign pollution is

$$\Delta z^* = (\theta^* - \lambda\theta)\,\frac{\gamma\delta\left((\beta-\alpha)-(\beta^*-\alpha^*)+\gamma(\eta\theta-\eta^*\theta^*)\right)}{2(\gamma+\delta)(\gamma+2\delta)} \tag{4.56}$$

Proposition 16. *When countries set pollution (production) quotas non-cooperatively, but otherwise pursue free trade and if the home country is a natural importer of X, i.e., if $(\beta-\alpha)+\gamma\eta\theta > (\beta^*-\alpha^*)+\gamma\eta^*\theta^*$,*

1. *if the marginal damage from domestic pollution is higher than that from transboundary pollution, i.e., if $\lambda < 1$, then pollution in the home (foreign) country increases when countries move from autarky to free trade if $\lambda > \frac{\theta}{\theta^*}$ ($\lambda < \frac{\theta^*}{\theta}$);*

2. *if pollution is a pure global public bad, i.e., if $\lambda = 1$, then world pollution may rise or fall due to trade liberalization; if the exporter's pollution intensity is higher (lower) than that of the importer's, i.e., if $\theta^* > (<)\theta$, then pollution increases (decreases).*

The change in the home country's welfare due to a movement from autarky to free trade is $\Delta W = W - W^a$, where W and W^a are welfare (as measured by Eq. (4.10)) under free trade and autarky respectively,

$$\begin{aligned}\Delta W \quad = & \quad \frac{\delta(3\gamma+4\delta)\left((\beta-\alpha)-(\beta^*-\alpha^*)+\gamma(\eta\theta-\eta^*\theta^*)\right)^2}{8(\gamma+\delta)(\gamma+2\delta)^2} \\ & - \frac{4\lambda\gamma\delta\eta\theta^*\left((\beta-\alpha)-(\beta^*-\alpha^*)+\gamma(\eta\theta-\eta^*\theta^*)\right)}{8(\gamma+\delta)(\gamma+2\delta)}\end{aligned} \tag{4.57}$$

If there is no motive for trade, i.e., if $(\beta-\alpha)+\gamma\eta\theta = (\beta^*-\alpha^*)+\gamma\eta^*\theta^*$, then $\Delta W = 0$. However, if the home country is a natural importer of X, i.e., if $(\beta-\alpha)+\gamma\eta\theta > (\beta^*-\alpha^*)+\gamma\eta^*\theta^*$, then it gains from, is unaffected by, or loses from trade liberalization if $((\beta-\alpha)-(\beta^*-\alpha^*)+\gamma(\eta\theta-\eta^*\theta^*)) \gtreqless \frac{4\gamma(\gamma+2\delta)}{(3\gamma+4\delta)}\lambda\eta\theta^*$.

المنارة للاستشارات
www.manaraa.com

The change in the foreign country's welfare due to trade liberalization is

$$\Delta W^* = \frac{\delta(3\gamma+4\delta)\left((\beta-\alpha)-(\beta^*-\alpha^*)+\gamma(\eta\theta-\eta^*\theta^*)\right)^2}{8(\gamma+\delta)(\gamma+2\delta)^2} + \frac{4\lambda\gamma\delta\eta^*\theta\left((\beta-\alpha)-(\beta^*-\alpha^*)+\gamma(\eta\theta-\eta^*\theta^*)\right)}{8(\gamma+\delta)(\gamma+2\delta)} \quad (4.58)$$

If the foreign country is a natural exporter of X, i.e., if $(\beta-\alpha)+\gamma\eta\theta > (\beta^*-\alpha^*)+\gamma\eta^*\theta^*$, then foreign welfare is unambiguously higher under free trade as compared to autarky.

The change in the aggregate (world) welfare due to trade liberalization is $\Delta W^w = \Delta W + \Delta W^*$,

$$\Delta W^w = \frac{\delta(3\gamma+4\delta)\left((\beta-\alpha)-(\beta^*-\alpha^*)+\gamma(\eta\theta-\eta^*\theta^*)\right)^2}{4(\gamma+\delta)(\gamma+2\delta)^2} - \frac{2\lambda\gamma\delta\left((\beta-\alpha)-(\beta^*-\alpha^*)+\gamma(\eta\theta-\eta^*\theta^*)\right)(\eta\theta^*-\eta^*\theta)}{4(\gamma+\delta)(\gamma+2\delta)} \quad (4.59)$$

Proposition 17. *If countries set pollution (or production) quotas non-cooperatively, but otherwise pursue free trade, then*

1. *if there is no motive for trade between the countries, i.e., if $(\beta-\alpha)+\gamma\eta\theta = (\beta^*-\alpha^*)+\gamma\eta^*\theta^*$, such that the autarky relative (consumer) price is the same in both countries, there is no welfare loss or gain in either country due to trade liberalization and there is no trade in equilibrium;*

2. *if there is a motive for trade between the countries, i.e., if $(\beta-\alpha)+\gamma\eta\theta \neq (\beta^*-\alpha^*)+\gamma\eta^*\theta^*$, the importer of the polluting good may gain or lose from trade liberalization, the exporter of the polluting good is unambiguously better off under free trade as compared to autarky, while the effect of trade liberalization on aggregate (world) welfare is ambiguous.*

4.6 Special Cases

In this section we look at three special cases of the model developed in this chapter.

4.6.1 Case 1: $(\beta-\alpha)-(\beta^*-\alpha^*)+\gamma(\eta\theta-\eta^*\theta^*)=0$, $\eta\theta > \eta^*\theta^*$

Consider a situation such that, without accounting for the environmental externality, the home country has a comparative advantage in the polluting good, X, i.e., $(\beta-\alpha) < (\beta^*-\alpha^*)$.

المنارة للاستشارات
www.manaraa.com

However, $\eta\theta > \eta^*\theta^*$, such that $\gamma(\eta\theta - \eta^*\theta^*) = -((\beta - \alpha) - (\beta^* - \alpha^*)) \Rightarrow (\beta - \alpha) - (\beta^* - \alpha^*) + \gamma(\eta\theta - \eta^*\theta^*) = 0$. This can be because the home country suffers a higher marginal disutility from pollution as compared to the foreign country ($\eta > \eta^*$) or production in the home country generates more emissions per unit of output as compared to the foreign country ($\theta > \theta^*$), among others.

The free trade Nash equilibrium taxes in the home and foreign countries are, respectively,

$$t = \eta\theta - \frac{\lambda\gamma\left((3\gamma + 4\delta)\eta\theta^* + \gamma\eta^*\theta\right)}{4(\gamma + \delta)(\gamma + 2\delta)} \tag{4.60}$$

$$t^* = \eta^*\theta^* - \frac{\lambda\gamma\left((3\gamma + 4\delta)\eta^*\theta + \gamma\eta\theta^*\right)}{4(\gamma + \delta)(\gamma + 2\delta)} \tag{4.61}$$

Note that in this case, as there is no terms of trade effect, the transboundary pollution effect, that tends to lower the domestic environmental tax, reduces the domestic environmental tax in both countries. Hence, the free trade pollution tax is lower than the optimal autarky tax in both countries. Furthermore, note that the sum of the taxes in the two countries, $t + t^* = \eta\theta + \eta^*\theta^* - \frac{\lambda\gamma(\eta\theta^* + \eta^*\theta)}{(\gamma + 2\delta)}$, is the same irrespective of the presence or absence of the terms of trade effect.

The change in the production tax on X in the home country, due to trade liberalization, is

$$t - t^a = -\frac{\lambda\gamma\left((3\gamma + 4\delta)\eta\theta^* + \gamma\eta^*\theta\right)}{4(\gamma + \delta)(\gamma + 2\delta)} < 0$$

and the change in the foreign country's output tax due to a movement from autarky to free trade is

$$t^* - t^{a*} = -\frac{\lambda\gamma\left((3\gamma + 4\delta)\eta^*\theta + \gamma\eta\theta^*\right)}{4(\gamma + \delta)(\gamma + 2\delta)} < 0$$

Hence, both countries reduce their tax on X due to trade liberalization.

The change in the home country's production of X is

$$\Delta x = \frac{\lambda\gamma^2\left((\gamma + 4\delta)\eta\theta^* - \gamma\eta^*\theta\right)}{4(\gamma + \delta)(\gamma + 2\delta)} \tag{4.62}$$

Suppose $\eta^*\theta < \eta\theta^*$; then, the home country's production of X increases due to trade liberalization. Similarly, the change in foreign production of X is

$$\Delta x^* = \frac{\lambda\gamma^2\left((\gamma + 4\delta)\eta^*\theta - \gamma\eta\theta^*\right)}{4(\gamma + \delta)(\gamma + 2\delta)} \tag{4.63}$$

المنارة للاستشارات
www.manaraa.com

Hence, $\Delta x^* \lesseqgtr 0$ as $\frac{\frac{\gamma}{\delta}+4}{\frac{\gamma}{\delta}} \lesseqgtr \frac{\eta}{\eta^*}\frac{\theta^*}{\theta}$. The change in the total world production of X is

$$\Delta x^w = \Delta x + \Delta x^* = \frac{\lambda\gamma^2\delta(\eta\theta^* + \eta^*\theta)}{(\gamma+\delta)(\gamma+2\delta)} > 0 \tag{4.64}$$

Hence, the change in total world production of X is the same as that in the presence of terms of trade effects, and is unambiguously positive when countries use taxes to regulate domestic pollution.

With Pareto efficient taxes (Eq. (4.18)) in both countries, if $\eta^*\theta < \eta\theta^*$, given the assumptions in this subsection, the home country should export X in the efficient equilibrium. When countries set domestic taxes non-cooperatively, then the home country exports X

$$M_x = \frac{\lambda\gamma^2(\eta^*\theta - \eta\theta^*)}{4(\gamma+\delta)} < 0, \quad \text{if} \quad \eta^*\theta < \eta\theta^*$$

Hence, the free trade tax equilibrium, although inefficient, results in the same direction of trade as the Pareto efficient equilibrium.

The increase in total pollution in the home and foreign countries due to trade liberalization are, respectively,

$$\Delta z = \frac{\lambda\gamma^2\left((\gamma+4\delta)(\eta+\lambda\eta^*)\theta\theta^* - \lambda\gamma(\eta\theta^{*2} + \eta^*\theta^2)\right)}{4(\gamma+\delta)(\gamma+2\delta)} \tag{4.65}$$

$$\Delta z^* = \frac{\lambda\gamma^2\left((\gamma+4\delta)(\eta^*+\lambda\eta)\theta\theta^* - \lambda\gamma(\eta^*\theta^2 + \eta\theta^{*2})\right)}{4(\gamma+\delta)(\gamma+2\delta)} \tag{4.66}$$

When pollution is a pure global public bad, i.e., $\lambda = 1$, the change in pollution due to a movement from autarky to free trade is

$$\Delta z^w = \frac{\gamma^2\left(((\gamma+4\delta)\theta^* - \gamma\theta)\eta^*\theta + ((\gamma+4\delta)\theta - \gamma\theta^*)\eta\theta^*\right)}{4(\gamma+\delta)(\gamma+2\delta)} \tag{4.67}$$

Furthermore, if $\theta = \theta^*$, then

$$\Delta z^w = \frac{\gamma^2\delta(\eta+\eta^*)\theta^2}{(\gamma+\delta)(\gamma+2\delta)} > 0$$

and total world pollution increases as a result of trade liberalization.

The change in the home country's welfare due to a movement from autarky to free trade is

$$\Delta W = \frac{\lambda^2\gamma^2(3\gamma+4\delta)\left(\gamma^2(\eta\theta^* - \eta^*\theta)^2 - 16\delta(\gamma+\delta)\eta\eta^*\theta\theta^*\right)}{32(\gamma+\delta)^2(\gamma+2\delta)^2} \tag{4.68}$$

المنارة للاستشارات
www.manaraa.com

Similarly, the change in foreign welfare resulting from trade liberalization is

$$\Delta W^* = \frac{\lambda^2\gamma^2(3\gamma+4\delta)\left(\gamma^2(\eta^*\theta-\eta\theta^*)^2-16\delta(\gamma+\delta)\eta\eta^*\theta\theta^*\right)}{32(\gamma+\delta)^2(\gamma+2\delta)^2} \tag{4.69}$$

Hence, either both countries gain or both lose from trade liberalization. Moreover, the gain (loss) in welfare in the two countries are identical. Both countries gain (lose) if

$$\frac{(\frac{\eta}{\eta^*}\frac{\theta^*}{\theta}-1)^2}{\frac{\eta}{\eta^*}\frac{\theta^*}{\theta}} > (<) \frac{16(\frac{\gamma}{\delta}+1)}{(\frac{\gamma}{\delta})^2}$$

As the ratio of the slopes of the supply and demand curves, $\frac{\gamma}{\delta}$, increases, it is more likely that countries gain from trade liberalization. The change in aggregate (world) welfare is

$$\Delta W^w = \frac{\lambda^2\gamma^2(3\gamma+4\delta)\left(\gamma^2(\eta^*\theta-\eta\theta^*)^2-16\delta(\gamma+\delta)\eta\eta^*\theta\theta^*\right)}{16(\gamma+\delta)^2(\gamma+2\delta)^2} \tag{4.70}$$

Now consider the situation when countries use quotas to regulate domestic pollution. From Eq.s (4.52) and (4.53) we have

$$\Delta x = \Delta x^* = 0$$

Hence, there is no change in the pollution level in either country due to trade liberalization. Furthermore, Eq.s (4.57) and (4.58) imply that neither country gains or loses as a result of moving from autarky to free trade. However, although there is no trade, the free trade quota equilibrium is also inefficient as countries do not internalize the effect of their emissions on the other country's welfare and the home country should export X in the Pareto efficient equilibrium.

Under the assumptions made in this subsection, we find that both countries lower their environmental tax and total world production of the polluting good increases under free trade as compared to autarky. Also, if pollution is a pure global public good, then pollution increases as a result of trade liberalization when both countries use an environmental tax to regulate domestic pollution. However, when the policy instrument is a quota, then there is no change in quota levels (hence, production and pollution) and welfare in either country due to the movement from autarky to free trade.

المنارة للاستشارات

www.manaraa.com

4.6.2 Case 2: $(\beta-\alpha)=(\beta^*-\alpha^*)$, $\theta^*=\theta$, $\lambda=1$, $\eta>\eta^*$

Now consider another situation when pollution is a pure global public bad ($\lambda = 1$) and the only difference between the two countries is in their marginal disutility from pollution. Assume that $\eta > \eta^*$, $\theta^* = \theta$ and $\beta-\alpha = \beta^*-\alpha^*$. The free trade Nash equilibrium taxes in the home and foreign countries are, respectively,

$$t = \eta\theta - \frac{\gamma\theta\left((2\gamma+3\delta)\eta-\delta\eta^*\right)}{2(\gamma+\delta)(\gamma+2\delta)} \tag{4.71}$$

$$t^* = \eta^*\theta - \frac{\gamma\theta\left((2\gamma+3\delta)\eta^*-\delta\eta\right)}{2(\gamma+\delta)(\gamma+2\delta)} \tag{4.72}$$

Note that, as shown before, the sum of the taxes in the two countries is $t+t^* = (\eta+\eta^*)\theta - \frac{\gamma\theta(\eta+\eta^*)}{(\gamma+2\delta)}$, and depends only on the pollution parameters, η, η^* and θ, and the slopes of the demand and supply curves, δ and γ.

The change in the production tax on the polluting good, X, in the home country is

$$t-t^a = -\frac{\gamma\theta\left((2\gamma+3\delta)\eta-\delta\eta^*\right)}{2(\gamma+\delta)(\gamma+2\delta)} < 0$$

Hence, the terms of trade effect and the transboundary pollution effect lead to lower environmental tax on X in the home country under free trade as compared to autarky. The change in the foreign country's output tax due to a movement from autarky to free trade is

$$t^*-t^{a*} = -\frac{\gamma\theta\left((2\gamma+3\delta)\eta^*-\delta\eta\right)}{2(\gamma+\delta)(\gamma+2\delta)}$$

Since $\eta > \eta^*$, the foreign country is a natural exporter of X, so the terms of trade effect (that tends to increase the tax on X) and the transboundary pollution effect (that tends to reduce the tax on X) work in opposite directions. The foreign country also reduces its tax on X due to trade liberalization if $\frac{\eta}{\eta^*} < 2\frac{\gamma}{\delta}+3$. Hence, as the ratio of the slopes of the supply and demand curves, $\frac{\gamma}{\delta}$, increases, it is more likely that the foreign country also reduces its tax on X. Also, the more similar both countries' preferences are towards pollution, the more likely it is that the foreign country also reduces its output tax. A sufficient condition for both countries to reduce their environmental taxes is $\eta^* < \eta < 3\eta^*$.

The change in the home country's production of X is

$$\Delta x = \frac{\gamma^2\delta\theta(\eta+\eta^*)}{2(\gamma+\delta)(\gamma+2\delta)} > 0 \tag{4.73}$$

المنارة للاستشارات
www.manaraa.com

Hence, the home country's production of X increases due to trade liberalization. Similarly, the change in foreign production of X is

$$\Delta x^* = \frac{\gamma^2\delta\theta(\eta+\eta^*)}{2(\gamma+\delta)(\gamma+2\delta)} > 0 \tag{4.74}$$

and, the foreign country also increases its production of X due to a movement from autarky to free trade. The change in the total world production of X is

$$\Delta x^w = \frac{\gamma^2\delta\theta(\eta+\eta^*)}{(\gamma+\delta)(\gamma+2\delta)} > 0 \tag{4.75}$$

which is unambiguously positive when countries use taxes to regulate domestic pollution.

Under the assumptions of this subsection, with Pareto efficient taxes, there is no trade in equilibrium. However, in the free trade equilibrium, when countries use taxes to regulate pollution, the home country imports X,

$$M_x = \frac{\gamma\delta\theta(\eta-\eta^*)}{2(\gamma+\delta)} > 0$$

Hence, the free trade equilibrium results in positive trade flows, whereas the Pareto efficient equilibrium results in no trade.

The change in pollution due to trade liberalization is

$$\Delta z^w = \theta\Delta x^w = \frac{\gamma^2\delta\theta^2(\eta+\eta^*)}{(\gamma+\delta)(\gamma+2\delta)} > 0 \tag{4.76}$$

Thus, pollution increases when countries move from autarky to free trade when both countries use taxes to regulate pollution.

The change in the home country's welfare due to a movement from autarky to free trade is

$$\Delta W = -\frac{\gamma^2\delta\theta^2\left[(4\gamma^2+9\gamma\delta+4\delta^2)\eta^2+2(4\gamma^2+11\gamma\delta+8\delta^2)\eta\eta^*-\delta(3\gamma+4\delta)\eta^{*2}\right]}{8(\gamma+\delta)^2(\gamma+2\delta)^2} < 0 \tag{4.77}$$

Since $\eta > \eta^*$, $\Delta W < 0$ and the home country loses as a result of trade liberalization. The change in the foreign country's welfare resulting from trade liberalization is

$$\Delta W^* = -\frac{\gamma^2\delta\theta^2\left[(4\gamma^2+9\gamma\delta+4\delta^2)\eta^{*2}+2(4\gamma^2+11\gamma\delta+8\delta^2)\eta\eta^*-\delta(3\gamma+4\delta)\eta^2\right]}{8(\gamma+\delta)^2(\gamma+2\delta)^2} \tag{4.78}$$

Hence, the foreign country loses (gains) from trade liberalization if

$$\left(3\frac{\gamma}{\delta}+4\right)\left(\frac{\eta}{\eta^*}\right)^2 < (>) \left[4\left(\frac{\gamma}{\delta}\right)^2+9\left(\frac{\gamma}{\delta}\right)+4\right]+2\left[4\left(\frac{\gamma}{\delta}\right)^2+11\left(\frac{\gamma}{\delta}\right)+8\right]\frac{\eta}{\eta^*}$$

www.manaraa.com

The change in aggregate (world) welfare is

$$\Delta W^w = -\frac{\gamma^2\delta\theta^2\left[\gamma(2\gamma+3\delta)\eta^2 + 2(4\gamma^2+11\gamma\delta+8\delta^2)\eta\eta^* + \gamma(2\gamma+3\delta)\eta^{*2}\right]}{4(\gamma+\delta)^2(\gamma+2\delta)^2} < 0 \tag{4.79}$$

Hence, when countries use taxes to regulate pollution, aggregate welfare is unambiguously lower under free trade as compared to autarky.

Now consider the case when countries use quotas to regulate domestic pollution. The non-cooperative free trade home and foreign quota levels are, respectively,

$$L = \frac{\gamma\beta+\alpha\delta}{\gamma+\delta} - \frac{\gamma\delta\theta\left((3\gamma+4\delta)\eta-\gamma\eta^*\right)}{2(\gamma+\delta)(\gamma+2\delta)} \tag{4.80}$$

$$L^* = \frac{\gamma\beta^*+\alpha^*\delta}{\gamma+\delta} - \frac{\gamma\delta\theta\left((3\gamma+4\delta)\eta^*-\gamma\eta\right)}{2(\gamma+\delta)(\gamma+2\delta)} \tag{4.81}$$

The change in the production of X due to trade liberalization in the home and foreign countries are[3], respectively,

$$\Delta x = x - x^a = L - L^a = -\frac{\gamma^2\delta\theta(\eta-\eta^*)}{2(\gamma+\delta)(\gamma+2\delta)} < 0 \tag{4.82}$$

$$\Delta x^* = x^* - x^{a*} = L^* - L^{a*} = \frac{\gamma^2\delta\theta(\eta-\eta^*)}{2(\gamma+\delta)(\gamma+2\delta)} > 0 \tag{4.83}$$

and the change in the world production of X is

$$\Delta x^w = \Delta x + \Delta x^* = 0 \tag{4.84}$$

The home country imports X,

$$M_x = \frac{\gamma\delta\theta(\eta-\eta^*)}{(\gamma+2\delta)} > 0$$

in the free trade quota equilibrium, while there is no trade in the Pareto efficient equilibrium.

Given that there is no change in the world production of X between autarky and free trade, there is also no change in pollution, i.e.,

$$\Delta z^w = 0 \tag{4.85}$$

The change in the home and foreign welfare due to trade liberalization are, respectively,

$$\Delta W = -\frac{\gamma^2\delta\theta^2(\eta-\eta^*)\left[(3\gamma+4\delta)\eta^* + (\gamma+4\delta)\eta\right]}{8(\gamma+\delta)(\gamma+2\delta)^2} < 0 \tag{4.86}$$

[3] Since the quotas bind in both countries, this is also the change in the quota levels.

المنارة للاستشارات
www.manaraa.com

$$\Delta W^{*} = \frac{\gamma^2\delta\theta^2(\eta-\eta^*)\left[(3\gamma+4\delta)\eta+(\gamma+4\delta)\eta^*\right]}{8(\gamma+\delta)(\gamma+2\delta)^2} > 0 \quad (4.87)$$

Hence, the home country loses and the foreign country gains from trade liberalization when both countries use quotas to regulate domestic pollution. The change in aggregate (world) welfare is

$$\Delta W^{w} = \frac{\gamma^3\delta\theta^2(\eta-\eta^*)^2}{4(\gamma+\delta)(\gamma+2\delta)^2} > 0 \quad (4.88)$$

Thus, when countries use quotas to regulate pollution, aggregate welfare increases due to trade liberalization, whereas when countries use taxes to regulate pollution, world welfare declines due to a movement from autarky to free trade.

When countries use taxes to regulate pollution, then under the assumptions of this subsection, production of the polluting good increases in both countries as a result of trade liberalization. Pollution increases and aggregate (world) welfare decreases due to the movement from autarky to free trade. However, when the policy instrument is a quota on production (or pollution), then production of X declines (increases) in the country with a higher (lower) marginal disutility from pollution, while aggregate (world) production and pollution are unchanged due to trade liberalization. The country with a higher marginal disutility from pollution loses, while the other country gains from trade liberalization and aggregate (world) welfare is higher under free trade as compared to autarky when quotas are the policy instruments in both countries.

4.6.3 Case 3: $(\beta-\alpha) > (\beta^*-\alpha^*)$, $\eta^*=\eta$, $\theta^*=\theta$

Here we consider the situation in which there is no difference between the countries with respect to pollution intensity or preference towards the environment, i.e., $\eta^* = \eta$ and $\theta^* = \theta$. However, there are differences in the demand and supply schedules of the two countries; specifically, the home country is a natural importer of the polluting good, X, i.e., $(\beta-\alpha) > (\beta^*-\alpha^*)$.

The free trade non-cooperative home and foreign country taxes on the production of X are, respectively,

$$t = \eta\theta - \frac{(\beta-\alpha)-(\beta^*-\alpha^*)}{4(\gamma+\delta)} - \frac{\lambda\gamma\eta\theta}{(\gamma+2\delta)} \quad (4.89)$$

www.manaraa.com

$$t^* = \eta\theta + \frac{(\beta-\alpha)-(\beta^*-\alpha^*)}{4(\gamma+\delta)} - \frac{\lambda\gamma\eta\theta}{(\gamma+2\delta)} \tag{4.90}$$

The sum of the taxes in the two countries is $t+t^* = 2(\eta\theta - \frac{\lambda\gamma\eta\theta}{(\gamma+2\delta)})$. The home country reduces its output tax due to trade liberalization

$$t - t^a = -\frac{(\beta-\alpha)-(\beta^*-\alpha^*)}{4(\gamma+\delta)} - \frac{\lambda\gamma\eta\theta}{(\gamma+2\delta)} < 0$$

This is because the terms of trade effect and the transboundary pollution effect reinforce each other to reduce t under free trade as compared to autarky. The change in the foreign country's tax due to trade liberalization is

$$t^* - t^{a*} = \frac{(\beta-\alpha)-(\beta^*-\alpha^*)}{4(\gamma+\delta)} - \frac{\lambda\gamma\eta\theta}{(\gamma+2\delta)}$$

The terms of trade effect and the transboundary pollution effect work in opposite directions in the foreign country; hence, $t^* < t^{a*}$ if the transboundary pollution effect dominates the terms of trade effect, i.e., if $\frac{\lambda\gamma\eta\theta}{(\gamma+2\delta)} > \frac{(\beta-\alpha)-(\beta^*-\alpha^*)}{4(\gamma+\delta)}$.

The change in the home and foreign production of X due to a movement from autarky to free trade are, respectively,

$$\Delta x = -\frac{\gamma((\beta-\alpha)-(\beta^*-\alpha^*))}{4(\gamma+\delta)} + \frac{\lambda\gamma^2\delta\eta\theta}{(\gamma+\delta)(\gamma+2\delta)} \tag{4.91}$$

$$\Delta x^* = \frac{\gamma((\beta-\alpha)-(\beta^*-\alpha^*))}{4(\gamma+\delta)} + \frac{\lambda\gamma^2\delta\eta\theta}{(\gamma+\delta)(\gamma+2\delta)} > 0 \tag{4.92}$$

Hence, $\Delta x > 0$ if $4\lambda\gamma\delta\eta\theta > (\gamma+2\delta)((\beta-\alpha)-(\beta^*-\alpha^*))$, and $\Delta x^* > 0$. The change in the world production of X as a result of trade liberalization is

$$\Delta x^w = \Delta x + \Delta x^* = \frac{\lambda\gamma^2\delta\eta\theta}{(\gamma+\delta)(\gamma+2\delta)} > 0 \tag{4.93}$$

i.e., total (world) production of X is unambiguously higher under free trade as compared to autarky.

Given the assumptions of this subsection, the home country imports X in the Pareto efficient equilibrium. When countries use taxes to regulate pollution, then the home country imports X in the free trade equilibrium,

$$M_x = \frac{(\gamma+2\delta)\,((\beta-\alpha)-(\beta^*-\alpha^*))}{4(\gamma+\delta)} > 0$$

المنارة للاستشارات
www.manaraa.com

and, although the free trade tax equilibrium is inefficient, it results in the same direction of trade as the Pareto efficient equilibrium.

The change in the home and foreign pollution due to a movement from autarky to free trade are, respectively,

$$\Delta z = \frac{(1+\lambda)\lambda\gamma^2\delta\eta\theta^2}{(\gamma+\delta)(\gamma+2\delta)} - \frac{(1-\lambda)\theta((\beta-\alpha)-(\beta^*-\alpha^*))}{4(\gamma+\delta)} \tag{4.94}$$

$$\Delta z^* = \frac{(1+\lambda)\lambda\gamma^2\delta\eta\theta^2}{(\gamma+\delta)(\gamma+2\delta)} + \frac{(1-\lambda)\theta((\beta-\alpha)-(\beta^*-\alpha^*))}{4(\gamma+\delta)} > 0 \tag{4.95}$$

Although domestic pollution may increase or decrease due to trade liberalization, foreign pollution unambiguously increases. Furthermore, if pollution is a pure global public bad, i.e., if $\lambda = 1$, then

$$\Delta z^w = \frac{2\gamma^2\delta\eta\theta^2}{(\gamma+\delta)(\gamma+2\delta)} > 0 \tag{4.96}$$

and pollution unambiguously increases under free trade as compared to autarky.

The change in the home country's welfare due to trade liberalization is

$$\Delta W = \frac{\lambda^2\gamma^2\eta^2\theta^2}{32(\gamma+2\delta)^2}\left[(3\mu+4)R^2 - 16R - \frac{16(3\mu+4)}{\mu(\mu+1)}\right] \tag{4.97}$$

where, $\mu \equiv \frac{\gamma}{\delta}$ and $R \equiv \frac{(\gamma+2\delta)}{\lambda\gamma\eta\theta}\frac{(\beta-\alpha)-(\beta^*-\alpha^*)}{(\gamma+\delta)}$. Hence, $\Delta W \gtreqless 0$ as $(3\mu+4)R^2 - 16R - \frac{16(3\mu+4)}{\mu(\mu+1)} \gtreqless 0$. Similarly, the change in the foreign country's welfare under free trade as compared to autarky is

$$\Delta W^* = \frac{\lambda^2\gamma^2\eta^2\theta^2}{32(\gamma+2\delta)^2}\left[(3\mu+4)R^2 + 16R - \frac{16(3\mu+4)}{\mu(\mu+1)}\right] \tag{4.98}$$

and the change in aggregate (world) welfare as a result of a movement from autarky to free trade is

$$\Delta W^w = \frac{\lambda^2\gamma^2\eta^2\theta^2(3\mu+4)}{16(\gamma+2\delta)^2}\left[R^2 - \frac{16}{\mu(\mu+1)}\right] \tag{4.99}$$

Hence, aggregate welfare increases (decreases) due to trade liberalization if $R^2 > (<) \frac{16}{\mu(\mu+1)}$.

When both countries use quotas to regulate emissions, the home and foreign free trade quota levels are, respectively,

$$L = \frac{(2\gamma+3\delta)\gamma\beta + (3\gamma+4\delta)\alpha\delta + \gamma\delta(\beta^*-\alpha^*)}{2(\gamma+\delta)(\gamma+2\delta)} - \frac{\gamma\delta}{\gamma+\delta}\eta\theta \tag{4.100}$$

المنارة للاستشارات
www.manaraa.com

$$L^* = \frac{(2\gamma+3\delta)\gamma\beta^* + (3\gamma+4\delta)\alpha^*\delta + \gamma\delta(\beta-\alpha)}{2(\gamma+\delta)(\gamma+2\delta)} - \frac{\gamma\delta}{\gamma+\delta}\eta\theta \qquad (4.101)$$

If the home country is a natural importer of X, the change in the production of X due to trade liberalization in the home and foreign countries are, respectively,

$$\Delta x = -\frac{\gamma\delta\left((\beta-\alpha)-(\beta^*-\alpha^*)\right)}{2(\gamma+\delta)(\gamma+2\delta)} < 0 \qquad (4.102)$$

$$\Delta x^* = \frac{\gamma\delta\left((\beta-\alpha)-(\beta^*-\alpha^*)\right)}{2(\gamma+\delta)(\gamma+2\delta)} > 0 \qquad (4.103)$$

and the change in world production of X is

$$\Delta x^w = \Delta x + \Delta x^* = 0 \qquad (4.104)$$

Hence, the home (foreign) country's production of X decreases (increases), while total world production is unchanged due to trade liberalization.

In the Pareto efficient equilibrium, the home country is an importer of X, and in the free trade quota equilibrium, the home country also imports X,

$$M_x = \frac{\delta\left((\beta-\alpha)-(\beta^*-\alpha^*)\right)}{(\gamma+2\delta)} > 0$$

Hence, the direction of trade are the same in the Pareto efficient and free trade quota equilibria, although the latter is inefficient.

The change in total pollution in the home country due to trade liberalization is

$$\Delta z = \theta\Delta x + \lambda\theta\Delta x^* = \frac{\theta(\lambda-1)\gamma\delta\left((\beta-\alpha)-(\beta^*-\alpha^*)\right)}{2(\gamma+\delta)(\gamma+2\delta)} < 0 \qquad (4.105)$$

Similarly, the change in foreign pollution is

$$\Delta z^* = \theta\Delta x^* + \lambda\theta\Delta x = \frac{\theta(1-\lambda)\gamma\delta\left((\beta-\alpha)-(\beta^*-\alpha^*)\right)}{2(\gamma+\delta)(\gamma+2\delta)} > 0 \qquad (4.106)$$

However, when pollution is a pure global public bad, i.e., $\lambda = 1$, pollution is unchanged as countries move from autarky to free trade.

The change in the home and foreign country's welfare due to trade liberalization are, respectively,

$$\Delta W = \frac{\delta\left((\beta-\alpha)-(\beta^*-\alpha^*)\right)\left((3\gamma+4\delta)\left((\beta-\alpha)-(\beta^*-\alpha^*)\right)-4\lambda\gamma(\gamma+2\delta)\eta\theta\right)}{8(\gamma+\delta)(\gamma+2\delta)^2} \qquad (4.107)$$

المنارة للاستشارات
www.manaraa.com

$$\Delta W^{*}=\frac{\delta\left((\beta-\alpha)-(\beta^{*}-\alpha^{*})\right)\left((3\gamma+4\delta)\left((\beta-\alpha)-(\beta^{*}-\alpha^{*})\right)+4\lambda\gamma(\gamma+2\delta)\eta\theta\right)}{8(\gamma+\delta)(\gamma+2\delta)^{2}}>0 \tag{4.108}$$

Hence, the home country gains (loses) from trade liberalization if $(\beta-\alpha)-(\beta^{*}-\alpha^{*})>(<)\frac{4\lambda\gamma\eta\theta(\gamma+2\delta)}{(3\gamma+4\delta)}$, and the foreign country always gains from trade liberalization. The change in aggregate (world) welfare is

$$\Delta W^{w}=\frac{\delta(3\gamma+4\delta)\left((\beta-\alpha)-(\beta^{*}-\alpha^{*})\right)^{2}}{4(\gamma+\delta)(\gamma+2\delta)^{2}}>0 \tag{4.109}$$

Thus, when countries use quotas to regulate pollution, aggregate welfare increases due to trade liberalization due to a movement from autarky to free trade.

When countries use taxes to regulate pollution, then under the assumptions made in this subsection, the natural importer of the polluting good lowers its environmental tax and the natural exporter may also reduce its tax, while total world production of X unambiguously increases due to trade liberalization. If pollution is a pure global public bad, then pollution is unambiguously higher under free trade as compared to autarky, although the effect of trade liberalization on aggregate world welfare is ambiguous. However, when both countries use quotas to regulate pollution, production of the polluting good and pollution in the natural importer (exporter) of X fall (rise), while total world production is unchanged due to trade liberalization. Aggregate world welfare is unambiguously higher under free trade as compared to autarky when the policy instrument in both countries is a quota on pollution.

4.7 Concluding Remarks

In this chapter we have extended the analysis of the previous chapter and explicitly modeled differences between countries that are involved in bilateral trade and are also affected by transboundary pollution from each other. Due to the presence of the transboundary pollution externality, Pareto efficiency requires that countries internalize both the domestic and transboundary effects of their emissions. Hence, the autarky equilibrium, in which countries internalize the domestic effects of pollution, but not the transboundary effects, is inefficient. We find that, even in the presence of (intrinsic) gains from trade, countries may lose from trade

المنارة للاستشارات
www.manaraa.com

liberalization if the welfare loss from increased pollution in the trading equilibrium dominates the gains from trade.

We find that, if the source of comparative advantage is the difference in preference towards pollution and pollution is a pure global public bad, then the country that suffers a higher marginal damage from pollution *lowers* its tax on the polluting good in the free trade equilibrium as compared to autarky. The other country may also lower its tax on the polluting good due to trade liberalization. The production of the polluting good (hence, pollution) unambiguously increases in both countries with trade liberalization, while aggregate (world) welfare declines when the policy instrument is a tax. However, when countries use quotas to regulate pollution, production of the polluting good decreases in the country that suffers a higher marginal disutility from pollution, while it increases in the other country, so that world production (hence, pollution) is unchanged as a result of a movement from autarky to free trade. Aggregate (world) welfare is higher under free trade as compared to autarky. Hence, comparing aggregate (world) welfare, the free trade quota equilibrium strictly welfare dominates the tax equilibrium. Again, this indicates that, in the presence of an international transboundary externality, when countries negotiate on free trade agreements, it might be beneficial to negotiate on the policy instrument that will be used in the countries to regulate the domestic externality.

We have analyzed the effect of trade liberalization on pollution and welfare in a static two country model. It would be interesting to extend this analysis to a dynamic model where pollution is a stock externality and look at the ranking of policy instruments. Another interesting avenue for future research is to analyze the effect of trade liberalization on pollution and welfare when, apart from the two large countries, there are other small (policy inactive) countries present and there is a change in production (hence, emissions) in these countries also.

المنارة للاستشارات
www.manaraa.com

CHAPTER 5. GENERAL CONCLUDING REMARKS

This dissertation analyzed optimal banking sector recapitalization programs and looked at the effects of trade liberalization on environmental policy, pollution and welfare when countries set domestic environmental policies non-cooperatively in the presence of an international transboundary externality.

In Chapter 2 we analyzed the Ramsey-optimal paths of banking sector recapitalization programs in the aftermath of a banking crisis. This is the first attempt at examining the public-finance aspect of the problem and the high fiscal costs of such programs underscores the importance of this analysis. We considered three different sources of financing: the government borrows from international debt markets to recapitalize banks, it funds the recapitalization program using non-distortionary (lump-sum) taxes and distortionary taxes are used to finance the recapitalization program.

Our results indicate that it is optimal to immediately recapitalize banks after a crisis if the government has access to international debt. Furthermore, by borrowing from international debt markets, the government can achieve perfect consumption smoothing. Without access to international debt, when lump-sum taxes finance the recapitalization program, it is not optimal to recapitalize banks immediately and when distortionary taxes are used, recapitalization of the bankrupt banking sector is even slower.

Although it has often been suggested that the government should restructure the banking system in one shot, we have shown that optimality requires a gradual approach unless the economy can borrow from international markets. This highlights the importance of having access to international debt markets during periods of financial distress. Thus, our results provide a rationale for international organizations extending emergency financing to developing

www.manaraa.com

countries that are recapitalizing their banking sectors in the aftermath of banking crises.

In Chapter 3 we explored the effects of a movement from autarky to free trade in the presence of transboundary pollution in a strategic setting. Pareto efficiency in such a situation requires that countries internalize both the domestic and transboundary welfare effects of its pollution; hence, the autarky equilibrium is inefficient as countries internalize only the former.

When countries use taxes to regulate pollution, trade liberalization can result in a race to the bottom in environmental taxes, that is welfare reducing. This is because of the transboundary pollution effect, which, due to carbon leakage, increases the incidence of transboundary pollution in the free trade equilibrium when countries regulate domestic pollution, thereby reducing the marginal benefit of regulating domestic pollution under free trade as compared to autarky. When the policy instrument is a quota, then there is no race to the bottom in environmental policy. However, when countries pursue free trade in goods and pollution permits, the outcome of trade liberalization depends on the public good nature of pollution. If pollution is a pure global public bad, there is no race to the bottom, but, if pollution is not a pure global public bad, there is a race to the bottom in environmental policy that leaves both countries worse off under free trade relative to autarky.

The internationally nontradable quota equilibrium welfare-dominates the internationally tradable quota equilibrium and is *strictly* welfare-superior to the tax equilibrium. We show that, even in the absence of terms of trade motives, purely the incentive, in a strategic setting, to under-regulate the domestic externality to reduce the incidence of the transboundary externality, can result in a race to the bottom in pollution policies, which leaves both countries worse off due to trade liberalization. Hence, when countries negotiate on free trade agreements, even if they do not negotiate on the exact level of the domestic policy, it might be beneficial to negotiate on the policy instrument that will be used to regulate the domestic externality due to the non-equivalence of policy instruments in the free trade equilibrium.

Chapter 4 extended the analysis of the previous chapter to explicitly model differences between two countries that are affected by transboundary pollution from each other and set domestic environmental policies non-cooperatively under free trade. The autarky and free trade

المنارة للاستشارات
www.manaraa.com

equilibria are both Pareto inefficient. We find that, even in the presence of potential gains from trade due to difference between the countries, the welfare loss from increased pollution in the free trade equilibrium may dominate and result in a net welfare loss from trade liberalization.

We analyzed some special cases and found that when pollution is a pure global public bad and the only source of comparative advantage stems from a difference in preference towards pollution between the two countries, pollution is higher (unchanged) under free trade when countries use taxes (quotas) to regulate pollution, as compared to autarky. Comparing aggregate (world) welfare, we find that the free trade quota equilibrium is welfare superior to autarky which is, in turn, welfare superior to the free trade tax equilibrium.

المنارة للاستشارات
www.manaraa.com

BIBLIOGRAPHY

Azzimonti, M., Sarte, P.-D., and Soares, J. (2006). Distortionary taxes and public investment when government promises are not enforceable. Working Paper.

Bagwell, K. and Staiger, R. W. (2001). Domestic policies, national sovereignty, and international economic institutions. *Quarterly Journal of Economics*, 116(2):519–562.

Caprio, G. and Klingebiel, D. (1996). Bank insolvencies: cross country experience. *World Bank Policy Research Working Paper*, (No. 1620).

Caprio, G. and Klingebiel, D. (2003). Episodes of systemic and borderline banking crises. World Bank.

Chava, S. and Purnanandam, A. (2006). The effect of banking crisis on bank-dependent borrowers. Working Paper.

Cole, H. and Ohanian, L. (2000). Re-examining the contribution of money and banking shocks to the U.S. Great Depression. *In: NBER Macroeconomics Annual*, pages 183–227. Vol 15. Eds. Ben Bernanke and Kenneth Rogoff.

Copeland, B. (1996). Pollution content tariffs, environmental rent shifting and the control of cross-border pollution. *Journal of International Economics*, 40:459–76.

Copeland, B. and Taylor, M. S. (1995). Trade and transboundary pollution. *American Economic Review*, 85(4):716–737.

Daniel, J., Davis, J., and Wolfe, A. (1997). Fiscal accounting of bank restructuring. IMF Paper on Policy Analysis and Assessment.

www.manaraa.com

Dell'Ariccia, G., Detragiache, E., and Rajan, R. (2005). The real effect of banking crises. IMF Working Paper.

Demiirgüç-Kunt, A. and Detragiache, E. (1998). The determinants of banking crises in developing and developed countries. *IMF Staff Papers*, 45(1):81–109.

Demiirgüç-Kunt, A., Detragiache, E., and Gupta, P. (2006). Inside the crisis: an empirical analysis of banking systems in distress. *Journal of International Money and Finance*, 25(5):702–718.

Honohan, P. and Klingebiel, D. (2000). Controlling the fiscal costs of banking crises. World Bank Policy Research Working Paper.

Ishikawa, J. and Kiyono, K. (2006). Greenhouse-gas emission controls in an open economy. *International Economic Review*, 47(2):431–450.

Kiyono, K. and Ishikawa, J. (2004). *International Economic Policies in a Globalized World*, chapter Strategic emission tax-quota non-equivalence under international carbon leakage, pages 133–150. Springer.

Kiyono, K. and Okuno-Fujiwara, M. (2003). Domestic and international strategic interactions in environment policy formation. *Economic Theory*, 21:613–633.

Klein, P., Krusell, P., and Ríos-Rull, J.-V. (2007). Time-consistent public policy. Working Paper.

Lindgreen, C.-J., Gillian, G., and Saal, M. (1996). *Bank Soundness and Macroeconomic Policy*. IMF.

Lucas, R. E. (1987). *Models of Business Cycles*. Blackwell.

Ludema, R. and Wooton, I. (1994). Cross-border externalities and trade liberalization: The strategic control of pollution. *Canadian Journal of Economics*, 27(4):950–966.

Markusen, J. (1975). International externalities and optimal tax structure. *Journal of International Economics*, 5:15–29.

المنارة للاستشارات
www.manaraa.com

Neumeyer, P. and Perri, F. (2005). Business cycles in emerging economies: the role of interest rates. *Journal of Monetary Economics*, 52:345–380.

Oviedo, P. M. and Sikdar, S. (2007). Optimal banking sector recapitalization. Iowa State University Working Paper.

Rauscher, M. (1997). *International Trade, Factor Movements and the Environment*. Claredon Press, Oxford.

Riascos, A. and Végh, C. (2004). Procyclical fiscal policy in developing countries: The role of capital market imperfections. Working Paper.

Romer, C. (1993). The Nation in Depression. *Journal of Economic Perspectives*, 7(2):19–39.

Sikdar, S. and Lapan H. E. (2007). Strategic environmental policy under free trade with transboundary pollution. Iowa State University Working Paper.

المنارة للاستشارات

www.manaraa.com