International Trade and Environmental Regulation: A Dynamic Perspective

by

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A dissertation submitted for the degree of Doctor of Philosophy at the
Australian National University

Submission: January 1999
Revision: May 1999

Declaration

This dissertation was written while I was studying at the Australia–Japan Research Centre, the Australian National University. The opinions expressed are my own, unless otherwise indicated.

Xinpeng Xu

January 1999

To Professor Peter Drysdale

Acknowledgements

I am deeply indebted to Professor Peter Drysdale. Without his generous support I would not have been able to pursue my Ph.D. study in Australia, and this dissertation would not have come into being. It is almost impossible to detail completely the contributions which he, as the chair of my dissertation committee, has made to this dissertation, simply because his influence is everywhere. He asked challenging questions when necessary, showed me how to improve the substance and style of the thesis, and gave support, both personal and academic, when it was most needed. I extend my heartfelt thanks to him. To him, this dissertation is dedicated.

I am grateful to Kali Kalirajian and Ben Smith, who also served on my committee. In particular, I thank Kali Kalirajian for the discussions on econometric studies and Ben Smith for his detailed remarks on certain chapters. Along with his friendship, Ligang Song provided constructive comments on each draft of the thesis.

I have had the good fortune to know and learn from two distinguished international trade theorists, Rod Falvey and Neil Vousden. The inspiration for this thesis came from Rod Falvey's challenging and stimulating course, 'Theory of International Trade', at the Australian National University. I will always be indebted to him for the strong research foundation that he imparted. Neil Vousden, as an adviser, has always very generously shared his time and his experience with me. In particular, I am grateful for his comments on Chapter 6. I deeply appreciate his friendship and his interest in my work.

Ross Garnaut, Peter Warr and Rod Tyers provided me with challenging research and teaching opportunities during the course of my doctoral program. Peter Lloyd has also been a constant source of encouragement. My highly esteemed teachers, Rod Falvey, Neil Vousden, Graeme Wells, John Robertson, Tom Kompas, Steve Dowrick, Simon Grant and John Logan have provided valuable insights and assistance over the past few years. I am grateful and proud that I have the opportunity to know and learn from them.

My gratitude also extends to my friends, Thomas P. Chen, Gary Klintworth, Wenquan Yin, Weiguo Lu, Yiping Huang, Tina Chen, Hongyan Wang, Dong Dong Zhang and Yongzheng Yang for their continuous encouragement and support.

Pam Hewitt's excellent editing improved the presentation of the thesis greatly. The Australia–Japan Research Centre and its staff, the International Economic Databank and its staff, and my fellow doctoral students at the Australian National University greatly assisted me throughout various phases of my research. I thank them all.

I also wish to thank the Australian National University for providing me with an ANU scholarship, and the Australian government for providing an Overseas Postgraduate Research Scholarship. These scholarships allowed me to complete my program and this dissertation.

Finally, I would like to thank my parents, my wife and my son, whose love, encouragement and support have made this journey an exhilarating one.

Xinpeng Xu
Canberra, January 1999.

Abstract

This study sets out to examine one of the most important issues on trade and the environment, namely, the trade effects of domestic environmental policy. The central question addressed is whether stringent domestic environmental policies reduce the international competitiveness of environmentally sensitive industries.

This study is distinguished by two major innovations that go beyond the established literature: the examination of time-series evidence to explore the relationship between environmental regulations and trade patterns, and the introduction of technology factors, together with endowment factors, to explain the empirical evidence.

There are five steps in the development of the argument. I first provide time-series evidence on the trade effects of environmental policy using the trade-in-goods approach. This is to investigate whether export patterns of environmentally sensitive goods (ESGs) have undergone systematic changes in the last three decades. The time-series evidence suggests that the export patterns for ESGs did not undergo systematic change, despite the introduction of stringent environmental standards in most developed countries in the 1970s and 1980s.

Secondly, I provide time-series evidence on the trade effects of environmental policy using a different approach, namely the factor-content-of-trade approach. The environment in this approach is regarded as a factor of production. This approach indicates that the net export content of environmental factor services for the majority

of the countries in the study did not experience systematic structural changes in the last three decades.

Thirdly, the time-series data are subjected to a multi-country econometric test using an extended gravity-equation framework. I test the following two hypotheses. The first is that more stringent environmental regulations lower total exports, and/or exports of ESGs, and/or exports of non-resource-based ESGs. The second is that new trade barriers emerge to offset the effects of more stringent environmental regulations. My findings reject both hypotheses. Overall, more stringent environmental regulations do not reduce total exports, exports of ESGs and exports of non-resource-based ESGs. There is no evidence to support the hypothesis that new trade barriers emerge to offset the effects of more stringent environmental regulations. Furthermore, higher import tariffs in trading partners are found to reduce significantly a reporter country's export performance in total exports, ESGs and non-resource-based ESGs. These results support the empirical time-series observations using both the trade-in-goods-approach and the factor-content-of-trade approach, and appear to reflect the extent to which increases in the stringency of environmental regulations are accompanied by technological innovation, which prevents the export performance of ESGs from deteriorating.

To explore the dynamic linkage between environmental regulation, technological innovation and economic growth theoretically, I set up an intertemporal dynamic general equilibrium model in which the more fundamental, dynamic determinant of economic growth is its capacity for technological innovation. The basic findings are that, (1) changes in the stringency of environmental regulations do not have long-run growth effects; and (2) technological innovation is an important determinant of a country's long-run growth.

Fifthly and finally, I investigate the significance of the technology factor, as proposed both in the above empirical study and the theoretical model, in determining the international competitiveness of environmentally sensitive industries. A generalised GDP function, which incorporates both technology change and increasing returns to scale, is set up and a flexible translog function form is used to approximate this generalised GDP function. Seemingly unrelated regression estimation (SURE) techniques are used to estimate a system of sectoral share equations derived from the generalised GDP function. Environmental stringency is treated as a factor of production together with capital, labour, land, mineral, oil and coal endowments. The technology level is regarded as an important determinant of the sectoral share in production. The basic hypothesis is that the environmental factor is not a significant determinant of the international competitiveness of environmentally sensitive industries, while technology is.

The econometric results suggest that the own-technology effects are all positive, as suggested by theory, and are statistically significant at a 5 per cent level in most cases. However, the environmental stringency variable has only a negligible effect and is shown to be statistically insignificant in all sectors. This suggests that countries with less stringent environmental policy do not necessarily have a higher sectoral share of ESGs.

The emphasis of this study is that the trade effects of domestic environmental policy can be better understood if one allows for a dynamic Ricardian technology factor in

the conventional Heckscher–Ohlin framework. Innovation and subsequent increases in relative labour productivity, together with factor endowments, are important factors in determining the relationship between environmental regulation and international competitiveness. This result should help refocus the debate on the relationship between environmental regulation and competitiveness in international trade.

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1 Trade Effects of Domestic Environmental Policy: the Issue

The origin of the issue

The second half of the twentieth century witnessed heightened concern and a vigorous debate on the interaction between trade and the environment at national, international and global levels. This is not surprising given that countries are becoming increasingly interdependent economically through international trade, that trade has been and continues to be an important channel for stimulating growth, and that people have more concern for their environment as income levels increase.

The intellectual history of trade and the environment has evolved in two waves (Levinson 1996). The first wave of research peaked in the late 1970s and seems to have been inspired by the introduction of stringent environmental regulations in developed countries from the early 1970s. The second wave occurred in the 1990s, mainly motivated by the debate over international trade agreements such as the North American Free Trade Agreement (NAFTA) and the Uruguay Round of the General Agreement on Tariffs and Trade (GATT). The current debate involves significant issues of environmental protection, export competitiveness, industry migration and the use of environmental regulations such as non-tariff trade barriers including eco-labeling (Bhagwati and Hudec 1996; Dean 1992). Although the policy debates relating to NAFTA and GATT may have subsided, fundamental long-term issues of trade and the environment remain.

There are three broad issues in the debate on trade and the environment: (a) How do domestic environmental policies affect trade? (b) How do trade policies affect the environment? (c) What is the relationship between international trade, environmental regulation and sustainable development? This thesis focuses on the first question.

Concerns about the effects of domestic environmental policies on trade have been expressed in the following ways. The first is the so-called 'race to the bottom' effect. Will trade with foreign countries with lower environmental standards force a domestic country to lower its own standards as a result of political pressures brought to bear on governments to ensure the survival of domestic industries? Will there be a tendency towards a 'race to the bottom' when trade among countries with different environmental standards is liberalised? This concern mainly emanates from countries with higher environmental standards.

The second concern is the so-called 'pollution haven' hypothesis (Walter and Ugelow 1979; Walter 1982). If free trade occurs between countries with different environmental standards, will countries with lower environmental standards tend, over time, to develop a comparative advantage[1] in environmentally sensitive industries with the result that 'havens' for the world's dirty industries emerge?[2] (Cropper and Oates 1992). The flip side of this concern is the fear that capital, and associated jobs, will move out of countries with high standards, a tendency termed 'industry flight'.

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[1] See Warr (1994) for an excellent discussion of the concepts of 'comparative advantage' and 'competitiveness'.

[2] Dirty industries here refer to environmentally sensitive industries. See Chapter 3 for a definition.

The third concern centres on export competitiveness. This is the debate over whether increasingly stringent domestic environmental regulations will reduce the international competitiveness of environmentally sensitive industries. The 'export competitiveness' line receives considerable attention whenever countries are in the process of passing new pollution control measures. This is not just an anxiety expressed by developed countries where environmental regulations are assumed to be more stringent, but it is also an issue of importance in developing countries, and one that affects significantly the development strategies of developing countries.

Fourth, there are concerns about unfair trade, 'eco-dumping'[3] and calls for 'level playing fields' and harmonisation of environmental standards across countries.[4] Trade with countries with lower environmental standards is regarded as 'unfair trade' because of the absence of a 'level playing field'. Such fears prompt calls for harmonisation of environmental standards across countries.

Fifth and finally, there are concerns expressed by developing countries, about a 'new protectionism' that uses trade measures such as import bans to achieve environmental goals,[5] and uses environmental measures such as eco-labeling to achieve economic goals.[6] Under this scenario, developing countries seeking to gain access to developed countries' markets view higher product or process standards, countervailing duties, or

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[3] See Chapter 7 for details.

[4] US Senator Boren, for example, introduced legislation in the US Congress to countervail the 'social dumping' allegedly resulting from lower standards abroad. He put such proposals forward on the grounds that: 'We can no longer stand idly by while some US manufacturers ... spend as much as 250 per cent more on environmental controls as a percentage of gross domestic product than do other countries. I see the unfair advantage enjoyed by other nations exploiting the environment and public health for economic gain when I look at many industries.' (Debate on the International Pollution Deterrence Act of 1991, statement of Senator David L. Boren, Senator Finance Committee, 25 October 1991, cited from Bhagwati and Srinivasan 1996).

[5] The US ban on imports of Mexican tuna caught using purse seine nets, which also kill dolphins, stands out as a case in point. Two GATT dispute resolution determinations concluded that the US measure violated trade rules. For details, see Esty (1994).

[6] Verbruggen, Kuik and Bennis (1995) note that 'Eco-labeling is, in fact, a form of product differentiation'.

import restrictions on goods and services produced in countries with lower environmental standards as a new form of protectionism.

At the heart of all these concerns is the impact of environmental standards on industrial competitiveness. If the impact of environmental standards on industrial competitiveness is negligible, there is no need to fear a 'race to the bottom'. If the impact of environmental standards on industrial competitiveness is trivial, 'dirty industries' will not migrate to locations with lower environmental standards and the 'pollution haven' hypothesis would be proved to be groundless. If the impact of environmental standards on industrial competitiveness is negligible, there would be no basis for arguments about 'level playing fields' and calls for harmonisation of international environmental standards.

Here lies the central issue of this study. Do stringent domestic environmental policies reduce the international competitiveness of environmentally sensitive industries?

Analytical framework

To identify an appropriate framework for this study, I take the recent debate between Porter and van der Linde (1995) and Palmer, Oates and Portney (1995) over the environment–competitiveness relationship as the starting point.

Porter and van der Linde (1995: 97) point out that the relationship between environmental regulations and international competitiveness has 'normally been thought of as involving a trade-off between social benefits and private costs'. 'One side pushes for tougher standards; the other side tries to beat the standards back.'

They argue that this view of the environment–competitiveness relationship 'has been framed incorrectly'. They propose that the environment–competitiveness relationship can be seen as 'complementary' rather than 'mutually exclusive' since 'properly designed environmental standards can trigger innovation that may partially or more than fully offset the costs of complying with them'.

However, Palmer, Oates and Porterny (1995) criticise this view and argue that there is always a trade-off between environmental regulations and international competitiveness. According to their simple, static model, if a firm has been operating at a certain abatement level without engaging in R&D, this implies that the cost of the R&D effort to reduce the marginal abatement cost to the required level exceeds the gains to the firm. In their model of innovation in abatement technology, an increase in the stringency of environmental regulations unambiguously disadvantages the polluting firm.

I now employ a simple unified model in which to evaluate the debate and as a basis for the subsequent work.

Suppose that the objective function of government is to maximise total net benefit, that is, the environmentally beneficial effects of regulation to society (social benefit), minus the cost to industry plus the discounted gain of innovation effects in the following periods arising from regulation. Notice in this formulation, there is not only a current gain but also an additional innovation effect that benefits the future. This is captured in the following intertemporal optimisation problem.

$$Max\int_{t}^{\infty}\{B_t(e_t)-[C_t(e_t)-R_t(e_t)]\}e^{-\rho t}dt \qquad \text{with respect to } e_t$$

where $B_t(e_t)$ and $C_t(e_t)$ are the social benefits and private costs arising from the introduction of e_t which denotes the stringency of environmental policy. $R_t(e_t)$ can be regarded as the benefits from innovation as a result of R&D in abatement technology and $(C_t(e_t)-R_t(e_t))$ is the net cost incurred to the firm.

The traditional approach compares the beneficial effects of regulation, $B_t(e_t)$ and the costs that must be borne to secure these benefits, $C_t(e_t)$. $R_t(e_t)$ is zero in this case since 'in this static world, where firms have already made their cost-minimizing choices, environmental regulation inevitably raises costs and will tend to reduce the market share of domestic companies on global markets' (Porter and van der Linde 1995: 97). According to Porter and van der Linde's (1995: 98) new paradigm, 'properly designed environmental standards can trigger innovation that may partially or more than fully offset the costs of complying with them'. That is, $R_t(e_t)$ is not zero. Porter and van der Linde's idea amounts to assuming $\partial R_t(e_t)/\partial e_t \geq 0$. There is an additional gain to the regulation in the form of innovation effects. In Porter and van der Linde's paper, environmental regulation cost and firm's profit is not a one-to-one trade-off (this is what 'partially or more than fully offset' means). This feature is essential to an understanding of the divide between Porter and van der Linde's argument and that of Palmer, Oates and Porterny (1995). The linkage between regulation and innovation as identified by Porter and van der Linde, however, is varied.

As demonstrated in Palmer, Oates and Porterny's (1995: 125) paper, even in a dynamic model, where firms minimise

$$Min\int_{t}^{\infty}(C_t(e_t) - R_t(e_t))e^{-\rho t}dt \qquad \text{with respect to } e_t$$

'if that technology wasn't worth investing in before, its benefits won't be enough to raise the company's profits after the environmental standards are raised, either'. Their model suggests that increasing the stringency of incentive-based environmental regulations must result in reduced profits for the firm. This is not, however, equivalent to the following condition, $\partial R_t(e_t)/\partial e_t = 0$. We can see clearly that even Palmer, Oates and Porterny (1995) admit that there exists a possibility that environmental regulation cost maybe partly offset by the benefits from adopting the new technology. What they emphasis is that this environmental regulation cost cannot be fully offset by the benefits from adopting the new technology so that environmental regulations must result in reduced profits for the firm. They also identify two possibilities that may give rise to an increase in profits following the imposition of tighter standards. One is strategic behaviour between firms and the other is the existence of opportunities for profitable innovation in the production of the firm's output that for some reason have been overlooked. Again, these two possibilities are proved to be groundless in their paper.

The divide between Porter and van der Linde (1995) and Palmer, Oates and Portney (1995) over the environment–competitiveness relationship is now clear. They both share the idea that there exists a possibility that environmental regulation cost maybe partly offset by the benefits from adopting the new technology (but it seems not to be acknowledged by Palmer, Oates and Portney). They differ on the question of whether this environmental regulation cost can be fully or more than fully offset by the benefits from adopting the new technology. However, The extent of this increase in benefits is a matter for empirical research. Lanjouw and Mody (1993) and Jaffe and Palmer (1997) provide broad empirical support for the argument that increases in environmental regulations will stimulate innovation.[7] A recent study by Berman and Bui (1998) using plant level data also suggests that environmental regulations are productivity-enhancing.

The above discussion is valid in the context of a closed economy. What are the implications for the environment–competitiveness relationship if the economy opens up to trade? Changes in domestic environmental policies can be thought of as changes in environmental factor endowments. Almost all the existing studies, for example Siebert (1977; 1987), Pethig (1976), McGuire (1982) and Baumol and Oates (1988), apply the conventional Heckscher–Ohlin–Vanek (H–O–V) theorem to analyse the theoretical impact of domestic environmental policies on trade flows. The standard result, as summarised in Siebert (1987), is that free trade will lead to a situation where the country with less stringent environmental regulations (higher environment factor endowment) will specialise in the production of pollution-intensive goods.

The limitations of this application of the H–O–V theorem lies in the fact that it explains little about the trade effects of domestic environmental policy. Existing empirical work consistently rejects the hypothesis that domestic environmental policy has a significant impact on trade.[8] This is not surprising given the fact that,

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[7] See Chapter 2 for further discussion.

[8] As surveyed by Dean (1992), 'there is little evidence of any significant impact of ECC (Environment Control Cost) on the pattern of trade'.

'[e]mpirically, the H–O–V theorem has been repeatedly rejected over the years and rightfully so: it performs horribly. Factor endowments correctly predict the direction of factor service trade about 50 per cent of the time, a success rate that is matched by a coin toss' (Trefler 1995: 1029). And this framework does not incorporate the theoretical challenge of 'new trade theory' on the H–O–V theorem which claims that it is unable to explain the prevalence of intra-industry trade.

Recent theoretical work by Davis (1995) introduces elements of Ricardian trade theory within the Heckscher–Ohlin (H–O) framework and successfully provides a unified account of intra-industry and inter-industry trade. Relative labour productivity, in the spirit of the Ricardian model, when combined with factor endowments, improves the explanations of changing trade patterns significantly, as Harrigan (1997) shows.[9]

Previous work provides some insights,[10] but is limited because it fails to take into account the long-term gains from R&D and innovation arising from stringent environmental regulation. In contrast, the framework I adopt in this study allows for consideration of both static endowment effects (changes in environmental standards) and technological innovation effects in determining growth and trade patterns. This extension is important, both in theoretical modelling and in empirical investigation, because it provides interesting insights into the underlying relationship between environmental regulation and industrial competitiveness. It is also consistent with recent theoretical developments, for example as demonstrated by Davis (1995).

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[9] See Chapter 2 for a detailed discussion of this literature and Chapter 6 for empirical measurement.
[10] For a detailed discussion of the literature, see Chapter 2.

Based on the above perspective, this study focuses on two main themes: time-series evidence and technological factors. A cross-sectional study is unsatisfactory because it may not be able to capture the dynamic effects of domestic environmental policy, especially the innovation and productivity effect $R_t(e_t)$. Time-series evidence, therefore, is one of the major features of the study. Since there are long-term gains from R&D and innovation, the subsequent increase in productivity has to be taken into account. Innovation and subsequent increases in relative labour productivity, together with factor endowments, are important factors in determining the environment–competitiveness relationship.

Structure of the study and major findings

The study is structured in the following way.

Chapter 2 examines the existing literature in detail, emphasising the nature of the debate, major findings and shortcomings. The directions and scope of the study are identified on the basis of this review.

In Chapter 3, I examine whether stringent environmental standards reduce the international competitiveness of environmentally sensitive industries using a comprehensive dataset of trade flows of environmentally sensitive goods (ESGs) disaggregated at the four-digit level of the Standard International Trade Classification. The data relate to the period from 1965 to 1995 and cover 34 countries, which accounted for nearly 80 per cent of world exports of ESGs in 1995. The important empirical finding is that the export performance of ESGs for most countries examined remained unchanged between the 1960s and 1990s despite the introduction of stringent environmental standards in most developed countries in the 1970s and 1980s. The claim that higher environmental standards reduce the international competitiveness of ESGs cannot be justified in the light of the available data.

In a complementary discussion of the trade-in-goods approach adopted in Chapter 3, Chapter 4 takes a different perspective by investigating the changing patterns of trade in embodied environmental factor services, a factor-content-of-trade approach. In this chapter, the environment is treated as a factor of production. I look at trade in embodied environmental factor services across more than 70 ISIC sectors for 29 countries in the period 1970–96. The result indicates that the net export content of environmental factor services for the majority of the countries in the study does not experience systematic structural change over the last 26 years, despite the introduction of stringent environmental regulations in most of the developed countries in the 1970s and 1980s. This observation is generally consistent with the observations in Chapter 3, using a trade-in-goods approach.

The above empirical time-series evidence is then subjected to a multi-country econometric test using an extended gravity-equation framework in Chapter 5. I test the following two hypotheses. The first is that more stringent environmental regulations lower total exports, and/or exports of ESGs, and/or exports of non-resource-based ESGs. The second is that new trade barriers emerge to offset the effects of more stringent environmental regulations. My findings reject the above two hypotheses. Overall, more stringent environmental regulations do not reduce total exports, exports of ESGs and exports of non-resource-based ESGs. There is no evidence to support the hypothesis that new trade barriers emerge to offset the effects of more stringent environmental regulations. Furthermore, higher import tariffs in trading partners are found to reduce significantly a reporter country's export performance in total exports, ESGs and non-resource-based ESGs exports. These results support the empirical time-series observations using both the trade-in-goods-approach and the factor-content-of-trade approach, and may reflect the extent to which increases in the stringency of environmental regulations are accompanied by technological innovation so that export performance of ESGs does not deteriorate.

Chapter 6 provides a formal endogenous growth model to capture the effects of technological innovation on a country's growth. A simple intertemporal optimisation problem is set up to address the issue of the effects of environmental policy on the output of environmentally sensitive goods (ESGs) and the growth rate of the economy. The basic findings are that (1) changes in the stringency of environmental regulations do not have long-run growth effects; and (2) technological innovation is an important determinant of a country's long-run growth.

Chapter 7 examines econometrically the significance of environmental policy for trade. A generalised GNP function, which incorporates both technology changes and increasing returns to scale, is set up and a flexible translog function form is used to approximate this generalised GNP function. Seemingly unrelated regression estimation (SURE) techniques are employed to estimate a system of sectoral share equations derived from the generalised GNP function. Environmental stringency is treated as a factor of production together with capital, labour, land, mineral, oil and coal endowments. The level of technology is regarded as an important determinant of the sectoral share in production. The basic hypothesis is that while the environmental factor is not a significant determinant of the international competitiveness of environmentally sensitive industries, technology is. The result supports this hypothesis and suggests that so-called eco-dumping is not an effective strategy in this context.

The final chapter summarises the major findings and policy implications of the study. Directions for future research are also identified.

2 International Trade, Environmental Regulation and the Competitiveness Debate: the Literature

Empirical evidence

Theory is subject to empirical test. It is therefore worthwhile to consider the empirical evidence before turning to theoretical models. This section considers the empirical evidence in the relationship between environmental policies and international trade[1].

Changes in the stringency of environmental policies may have implications not only for the domestic economy, but also for international trade. The impact of domestic environmental policy on international trade is generally traced in one of the following two ways:[2] (1) examining directly the effects of changing abatement costs on trade flows of ESGs across countries over time; and (2) investigating the changing trade patterns of ESGs.

Studies examining directly the effects of changing abatement costs on trade flows of ESGs include Walter (1973), Robison (1988), Kalt (1988), Leonard (1988), Tobey (1990), Grossman and Krueger (1993), Van Beers and van den Bergh (1997), among others. Low and Yeats (1992) and Sorsa (1994), on the other hand, examine the changing trade pattern of ESGs directly.

Walter[3] (1973) looks into the pollution content of US trade using input–output

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[1] For a discussion on changing environmental control expenditures, see Jaffe *et al* (1995).

[2] Dean (1992) and Levinson (1996) also survey the empirical evidence.

[3] See Chapter 4 for a detailed discussion of Walter (1973) and Robison's (1988) papers.

analysis. In that study, direct and overall environmental control charges (including those from intermediate goods) for 83 goods and services categories contained in the 1966 US input–output table are calculated. The pollution content of US exports is found to be 1.75 per cent of total exports while the pollution content of US imports is found to be 1.52 per cent of total imports. Walter considers this difference to be insignificant, and concludes that ESGs are trade-neutral at best and marginally biased against US export industries at worst.

Robison (1988) also investigates trade in embodied environmental factor services. He also looks into the pollution content of US trade in 1973, 1977 and 1982 using 1973 and 1977 input–output tables. This discrete time-series result indicates that the ratio of the abatement content of US imports to US exports has risen from 1.151 in 1973, to 1.167 in 1977 and 1.389 in 1982. On the basis of this result, Robison concludes that there is some evidence that US pollution control programs have changed US comparative advantage such that more high-abatement-cost goods will be imported and more low-abatement-cost goods exported.

Using a conventional Heckscher–Ohlin framework at a disaggregated industry level in the United States, Kalt (1988) regresses net exports of the *i*th industry on that industry's use of the national endowment of factors of production. These include: each industry's use of capital services (K_i), flows of research and development inputs to each industry ($R\&D_i$), flows of human capital services to each industry ($\mathrm{HK}_{i,}$), each industry's claim to the flow of low-skilled labour services ($\mathrm{UNSKILL}_{i,}$), and expenditures on pollution abatement services by each industry (ABATE_i).

$$\mathrm{NET}_i = f\,(\mathrm{K}_i, R\&D_i, \mathrm{HK}_i, \mathrm{UNSKILL}_i, \mathrm{ABATE}_i)$$

Kalt (1988) shows that domestic environmental regulation appears to have a negative effect on industries' trade performance.

By contrast, Leonard (1988) found little evidence that pollution control measures have exerted a systematic effect on international trade and investment by conducting a large case study of trade and foreign investment flows for several key industries and countries.

Tobey (1990) sets up a Heckscher–Ohlin–Vanek (H–O–V) multi-factor, multi-commodity model. Using 1975 data for 23 countries, Tobey regresses the net exports of five different industries that are classified as pollution intensive on the stocks of productive factors, including the environment. The environment variable Tobey uses is the stringency of environmental regulations, varying from 1 to 7, acting as the proxy for the stock of the environment. A country with more stringent regulations is assumed to have a lower environment stock than other countries. He found no evidence that the introduction of environmental control measures has caused trade patterns to deviate from the H–O–V predictions.

Grossman and Krueger (1993) investigate empirically the environmental impacts of NAFTA. They regress 1987 US imports from Mexico (relative to total US shipments) in 135 industries on factor shares which reflect the factor intensity of each industry. Environmental intensity is approximated by the ratio of pollution abatement costs to total value added in that US industry. Grossman and Krueger find that the traditional determinants of trade and investment patterns are significant, but that the alleged competitive advantages created by lax pollution controls in Mexico play no substantial role in motivating trade and investment flows.

A recent study by Van Beers and van den Bergh (1997) applies a gravity model to examine the impact of relatively strict environmental regulations on a country's exports and imports. Their study differs from the conventional H–O–V framework in that bilateral trade flows rather than aggregate trade flows are examined. They argue that a disadvantage of the H–O–V approach, which is based on multilateral trade flows, is that the effects of differences in strict environmental regulations on trade flows between countries may cancel out as multilateral trade is an aggregate of bilateral trade flows. Their cross-sectional study for 1992 shows that the broadly defined environmental stringency variable does not exert significant effects on bilateral trade flows while the narrow one (more directly linked to the Polluter Pays Principle) reveals a significant negative impact on exports. In the case of trade flows of pollution-intensive goods used as an independent variable, no effect of a relatively stringent environmental policy on exports of pollution intensive goods is found. They distinguish between resource-based and non-resource-based (or footloose) bilateral trade flows and find that stringent environmental policy does have a significant negative impact on non-resource-based exports. Although their work provides some interesting insights, there are two major limitations. Since their sample consists of (21) OECD countries only, there is an obvious sample selection bias problem, the reason simply being that trade effects of domestic environmental policy are more a North–South problem than a North–North problem[4]. A technical deficiency relating to their data is that macro fluctuation is not properly taken into account. As will be discussed in more detailed in Chapter 4, this might bias the results substantially.

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[4] See Page 2 to 3 for detailed discussions.

In general, one shortcoming of the existing literature is that the changing pattern of export performance of ESGs over time is seldom explored. This leads to an incomplete picture of the impact of environmental standards on industrial competitiveness. Low and Yeats (1992) first explored this issue by analysing sectoral changes that occurred in developed and developing countries' actual trade and revealed comparative advantage in heavily polluting industries. Their result indicates that developing countries gained a comparative advantage in pollution-intensive products at a greater rate than developed countries. The limitation of this study is that it focuses on one particular industry (iron and steel pipes and tubes, SITC 678) and, when considering the ESG groups, it only looks at the overall performance of two groups of countries, namely developed countries and developing countries. The study also only looks at the beginning (late 1960s) and end years (late 1980s). All this might result in an incomplete picture of the changing pattern of export performance of ESGs over time. Sorsa (1994) also examines this issue but at a more aggregated level.

As Levinson (1996: 450) concludes, '[t]he literature surveyed is almost unanimous in its conclusion that environmental regulations have not affected inter-jurisdictional trade or the location decisions of manufacturers. Where studies have found statistically significant effects of these regulations, the effects are always quite small.'

Turning now to the empirical evidence on the dynamic effects of environmental regulations, there are two studies that look explicitly at the relationship between stringency of environmental regulation and development of new technology. Lanjouw and Mody (1993) analyse the impact of stringent environmental regulations on the patenting of environmental technologies, using international data on expenditure on compliance with environmental regulation and environmental patents. Their results indicate that increases in environmental compliance costs lead to increases in the patenting of new environmental technologies, after a one- to two-year lag.

Jaffe and Palmer (1997) analyse the same issue in an econometric study using pollution control expenditure (PACE) data and value-added data by industry over time (1977–91) in the United States available from the Census Bureau's Pollution Abatement Costs and Expenditure Survey, and R&D data from the National Science Foundation. They estimate a highly reduced-form equation,

$$\text{Log}\ (R\&D) = f\,(\log(\textit{value added}), \log\ (\textit{government}\ R\&D), \log\ (PACE))$$

Although they find no statistically significant relationships between regulatory compliance expenditures and patenting activity, they do find that there exists a significant positive relationship between regulatory compliance expenditures and R&D expenditures by the regulated industry, which is broadly consistent with the findings of Lanjouw and Mody (1993).

A study by Berman and Bui (1998), using plant level data between 1979 and 1992, examines the effect of air quality regulation on the productivity of some of the most heavily regulated manufacturing plants in the United States, the oil refineries of the Los Angeles Air Basin. Their major finding includes the observation that despite the high costs associated with the local regulations, productivity in the Los Angeles Air Basin refineries rose sharply during the 1987–92 period, a period of decreased refinery productivity in other regions. They conclude that abatement may be productive.These findings suggest that the relationship between environmental regulation and competitiveness is not a zero-sum game. This relationship should be examined in a dynamic context where R&D and innovation play important roles. The theory and empirics of this issue will be examined further in Chapters 5, 6 and 7.

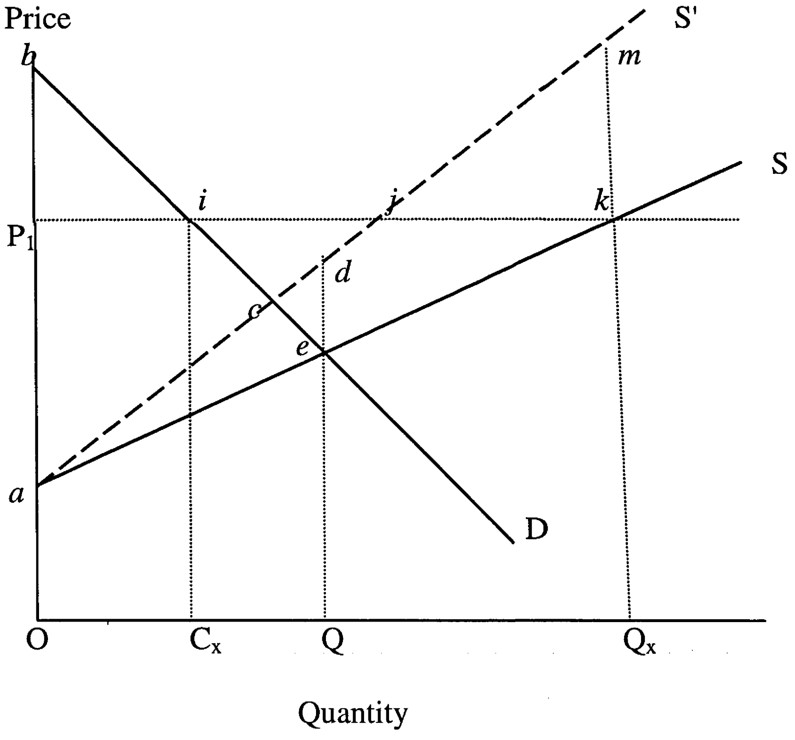
The main conclusion of more than 20 years of these types of empirical study seems to be that the trade effect of environmental regulations is insignificant. A number of theoretical models have been developed in an attempt to explain the link between environmental regulations and trade. However, to date, the theory has provided a rather inadequate explanation of the empirical evidence. This section is devoted to a survey of this literature with particular emphasis on the methodological differences of three different approaches.

Partial equilibrium approach: static, without innovation

The salient feature of the partial equilibrium model is that it analyses only one single, isolated market without taking into account the response from other markets. Most partial equilibrium models also introduce externality theory into the discussion of interactions between trade and the environment. This differs from most general equilibrium models which do not discuss externalities, instead taking environmental policy as an exogenous variable. One advantage of this modelling strategy is that the welfare effect of environmental and trade policies can easily be analysed. Although most partial equilibrium models on trade and environment focus on the effects on environment of trade and/or environmental policy changes, the trade effects of environmental policy can only be drawn indirectly.

Anderson (1992) provides a comprehensive comparative-static analysis of the welfare and environment effects of trade liberalisation. Consider a small economy producing a pollution-intensive good which results in a production externality. The result of the externality is to drive a wedge between the private and the social costs of production, as reflected in Figure 2.1 by S and S', respectively. The marginal private benefit from consuming is represented by the D curve. In the absence of either a pollution tax or international trade, OQ would be the equilibrium level of production, yielding net social welfare equal to the difference between the areas *abe* and *ade*.

Figure 2.1 Effects of opening up a small economy to trade in a product whose production is pollutive: the case of exportables



Source: Anderson (1992: 28).

If OP_1 were the international price, the country would become a net exporter of C_xQ_x units of the good under free trade. Net social welfare would be *abik* - *akm*, so the welfare effect of trade liberalisation relative to autarky is *eik* - *dekm*, which may be positive or negative depending on the relative magnitude of the gains from trade (*eik*) in the absence of externalities associated with the extra production versus the loss from increased the (uncharged) cost of pollution by producing an additional QQ_x units of this product (*dekm*). This leads to the proposition that liberalising trade in this good whose production is pollutive may or may not improve the welfare in this small economy in the absence of a pollution tax if, following the policy change, the country exports this good (Anderson 1992: 27).[5]

I now make use of this simple partial equilibrium device to investigate the trade effects of domestic environmental policy changes. Again, suppose in the absence of a pollution tax, the marginal private cost of producing a good that is pollutive and the marginal private benefits can be represented by the S and D curves in Figure 2.2, respectively, OQ is the autarky equilibrium level of production in the absence of a pollution tax. If OP_1 is the prevailing international price, this country will export C_xQ_x units of this good under free trade. Now, the country is concerned with the externalities arising from the production of the good that is pollutive and imposes an *ad valorum* pollution tax on the good. This can be represented by a shift of the supply curve from S to S', resulting in a decrease in the country's exports of this pollution-intensive good to C_xQ_x' . Therefore, the most simple partial equilibrium model predicts that an increase in the stringency of domestic environmental policy reduces the international competitiveness of ESGs. This is exactly the underlying mechanism that people are concerned about in the environment–competitiveness relationship. However, two points should be kept in mind when drawing real-world implications from the above analysis. One is that this is a partial equilibrium model in that it only

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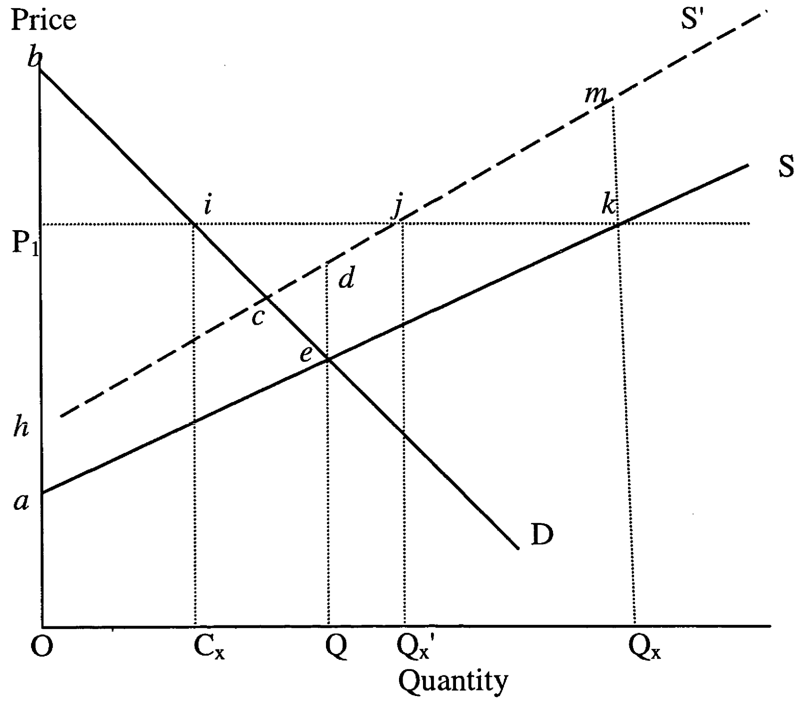
[5] Anderson (1992) also analyses the case of imports and other comparative-static effects. See Anderson (1992) for details.

takes account of one single, isolated market. The other is that it is static in nature and it is therefore subject to Porter and van der Linde's (1995) criticism.

Figure 2.2 Trade effects of domestic environmental policy changes: the case of exportables



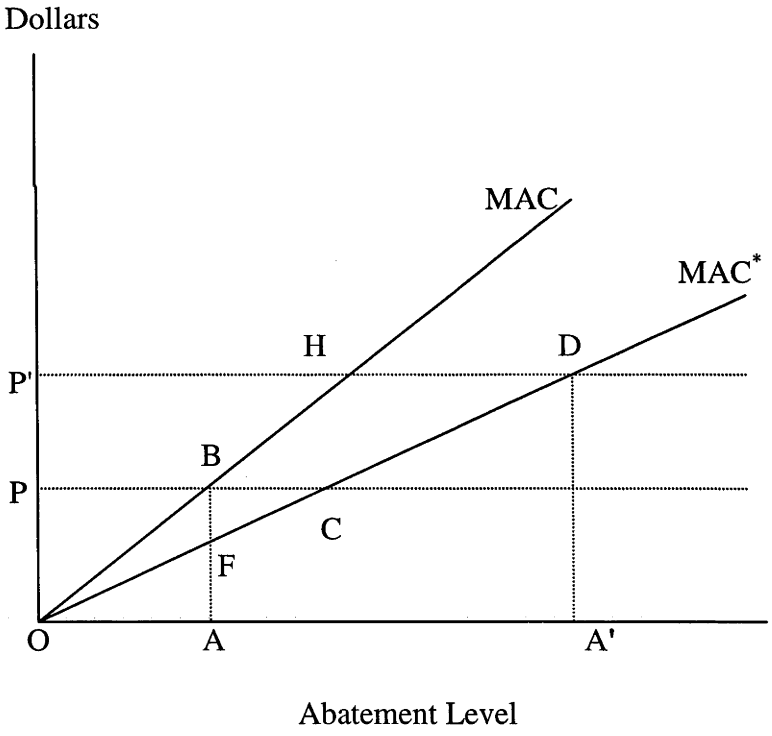
Source: Author's drawing on the basis of Anderson (1992: 28).

Innovation in a partial equilibrium model

The above comparative static partial equilibrium analysis sheds considerable light on the welfare effects of trade and/or environmental policy and provides some insights into the trade effects of domestic environmental policy. Notwithstanding, it is less helpful in understanding the environment–competitiveness debate, notably the 'new paradigm' suggested by Porter and van der Linde (1995) in which innovation plays a crucial role. According to Porter and van der Linde (1995: 97–98), '[t]he new paradim of international competitiveness is a dynamic one, based on innovation'.

In order to capture the effect of innovation, Palmer, Oates and Portney (1995), drawing on some of the earlier literature on innovation in abatement technology, present a model in which incentive-based environmental regulation results in reduced profits for the regulated firm. The assumptions include: (1) polluting firms are profit maximisers; (2) markets are perfectly competitive; (3) each firm takes competitors' outputs and R&D expenditures as given and also takes any regulations as exogenously determined (which implies there is no strategic interaction between firms, or between the polluting firm and the regulator).

Figure 2.3 Incentive to innovate under an emission fee



Source: Palmer, Oates and Portney (1995: 123).

Consider Figure 2.3 where the horizontal axis denotes the firm's abatement level and the vertical axis measures dollar values so that the marginal abatement cost (MAC) without innovation and the marginal abatement cost under innovation (MAC*) can be compared on the same dollar basis. The upward slope of the curve implies an increasing marginal cost, both for MAC and MAC*. Suppose that the initial effluent charge is at P and under this regime the polluting firm chooses its profit-maximising level of abatement activity A, corresponding to the point B, where marginal abatement cost equals the effluent charge. If this is observed, this implies that the cost of the R&D effort to reduce MAC to MAC* must exceed the gains to the firm under the above assumptions. Therefore the outcome B (without R&D) must produce more profits for the firm than does the attainable point C under which R&D is undertaken. The gain to the firm from R&D effort is given by the area OCB, which can be further decomposed into two areas: (1) the triangle OBF indicating cost reduction for the earlier level of abatement activity due to the new technology and (2) the triangle BCF which comes from a higher abatement level at lower abatement cost due to new technology. Since the firm has not chosen this option under this regulation scheme, it must be that the cost of the R&D efforts that would move the firm from MAC to MAC* exceeds the profits that would be gained, OCB.

Now, suppose a new, more stringent incentive-based environmental regulation is introduced, taking the form of an increase in the effluent fee to P'. The question of interest is whether the firm will respond to the higher effluent charge by sticking with the old technology, ending up at H, or by investing in the new one, ending up at D. If technology is constant so that MAC* remains the same, it is easy to show that profits at choice D (given the higher effluent charge) are less than profits at point C (given the lower previous effluent charge) along the MAC* frontier. Since profits are lower at C than at B, as observed under the old regulation regime, profits at D must be less than at B. This leads to the conclusion that the higher effluent charge reduces profits for the firm, even if it adopts new technology.

Although this model provides an interesting starting point for the environment–competitiveness debate, it has several limitations. First, it is static in nature. There is no underlying behavioural function describing the dynamic R&D innovation process. Second, the marginal abatement cost function under the new technology, MAC*, is a function of abatement level only. This is a very restrictive assumption since changes of regulation regime may imply changes in relative input prices and MAC* should be a function of this changing prices if the polluting firm is a profit maximiser. Third, it is partial in nature and therefore may not be able to capture the general equilibrium effects of changes of domestic environmental policies[6]. This leads us to a discussion of general equilibrium models.

General equilibrium models (I): the Heckscher–Ohlin approach

The literature on the trade effects of domestic environmental policy applying a general equilibrium approach generally develops along the lines of the Heckscher–Ohlin (H–O) model.

Since the 1970s most of the studies have analysed the theoretical impact of domestic environmental policy on trade patterns and predict that a country will export environmentally sensitive goods if it has less stringent environmental regulations and hence a relatively abundant environmental factor service. See, for example, Siebert, Eichberger, Gronych and Pethig (1980), Siebert (1977, 1987), Pethig (1976), Mcguire

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[6] Note that the last effect includes the change in prices.

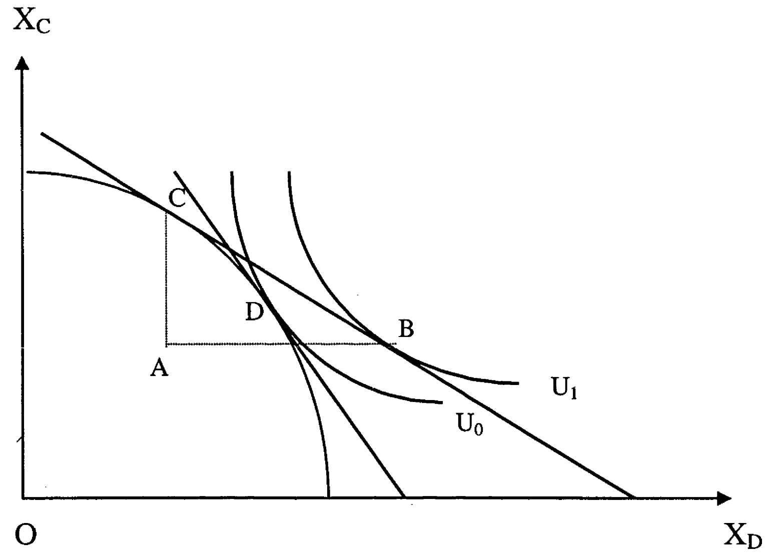
(1982), and Baumol and Oates (1988). With recent papers by Scott and Taylor (1994) using a demand and supply general equilibrium device and Chichilnisky (1994) looking at North–South trade from the perspective of property rights, their results are also mainly in the spirit of the H–O theorem.

Falvey (1994) summarises the following five standard assumptions of the H–O model that trade theorists have traditionally chosen to work with.

1) Dimensionality. There are two countries, *n* products and *m* factors of production. Each country is endowed with a fixed stock of each of the factors.
2) Mobility. Factors can move without cost among industries within a country, but are completely immobile internationally.
3) Competition. All agents are price takers in product and factor markets. Producers maximise profits and factor returns adjust to ensure full employment of all factors.
4) Technology. Production functions for all products exhibit constant returns to scale and diminishing marginal products of factors. Each country has the same productive technology for each good. There are no factor intensity reversals.
5) Tastes. Consumers everywhere have identical homothetic utility functions.

For simplicity, assume that there are two groups of commodities, pollution-intensive goods (X_D) and non-pollution-intensive goods (X_C); there are two inputs, environment (E) and labour (L), no trans-border pollution and consumption pollution; and that the costs of environmental damage are optimally internalised via emission charges (τ). Under these assumptions, the standard results of the H–O theorem in the context of trade and environment can be derived. They can be stated as follows. Under free trade, a country will export pollution-intensive goods (X_D) if it has a relatively abundant environmental factor service (E) and will import non-pollution-intensive goods (X_C), as shown in Figure 2.4.

Figure 2.4 Trade triangle



Source: Author's drawing.

Here relative factor abundance is defined in terms of the relative quantities of the factors in the two countries' endowments. The logic underlying this result is straightforward. Identical technologies and factor prices imply that identical factor proportions are used in each industry across countries. To achieve full employment, the relatively environmentally-abundant country will have to employ relatively more of its resources in the pollution-intensive sector. If products are consumed in the same proportions in each country, this implies that pollution-intensive goods will be exported.

Pethig (1976) derived several versions of the theorem of comparative advantage with respect to environmental scarcity. For example, in his theorem 4 (p. 168), Pethig concludes that 'a country exports and specializes in the production of the environment-intensive good, if its environmental control ... is less restrictive than the other country'.

Siebert (1987: 156), too, extends the H–O theorem to trade with pollution-intensive commodities and concludes that 'the environmentally rich country will export the pollution-intensive commodity'.

Baumol and Oates (1988: 265) summarise the trade effects of environmental policy in a somewhat different way. In their proposition five, '[a] country that fails to undertake an environmental protection program when other countries do so increases its comparative advantage (decreases its comparative disadvantage) in the production of items that damage its environment; in the absence of offsetting subsidies, this will encourage greater specialization in the production of these polluting outputs'.

Not surprisingly, the result that under free trade a country will export pollution-intensive goods if it has a relatively abundant environmental factor service is to some extent similar to the result gained from the partial equilibrium theorem. The common theme behind both partial and general H–O theorems is that an increase in the stringency of environmental regulation will lead to a loss of competitiveness in ESGs. This result lends support to the concerns of those in the affected industries and has been a persistent concern to both poor and wealthy countries.

Copeland and Taylor (1995) provide a simple demand and supply general equilibrium model (a highly simplified version of Copeland and Taylor's 1994 paper) that is useful when examining the literature. Although this is a synthesised analytical model, it is still in the spirit of the Heckscher–Ohlin theorem.

Suppose that all pollution is generated by production, that pollution harms consumers but does not affect production possibilities, and that pollution has only localised effects. The supply of pollution is the amount of pollution a country is willing to allow and depends not only on individual preferences, but also on the political process that transforms preferences into policies, and on the institutional framework that determines the types of policy adopted. The agent's indirect utility is given specifically by $V(p, I, Z) = \ln [I/h(p)] - \beta Z$, where Z is pollution, β is a positive constant, p is a goods price vector, I is income and h(p) is a price index. Income is determined by G(p, v, Z), where v is the endowment vector of primary factors and Z is the economy's supply of the 'input' pollution. Utility maximisation implies that

$$V_I * I_Z + V_Z = 0 \qquad (2.1)$$

where subscripts denote a partial derivative. I_Z is simply the shadow price of pollution (the optimal pollution tax), denoted by τ. Thus

$$\tau = - V_Z/V_I \qquad (2.2)$$

From the specification of the indirect utility function, we can obtain

$$V_Z = - \beta \text{ and } V_I = I. \qquad (2.3)$$

Note that if labour is the only primary factor of production, income is simply

$$I = wL + \tau Z. \qquad (2.4)$$

Substituting (2.3) into equation (2.2) and then combining (2.2) with (2.4) yields

$$\rho \equiv \tau/w = \beta L/(1-\beta Z) \qquad (2.5)$$

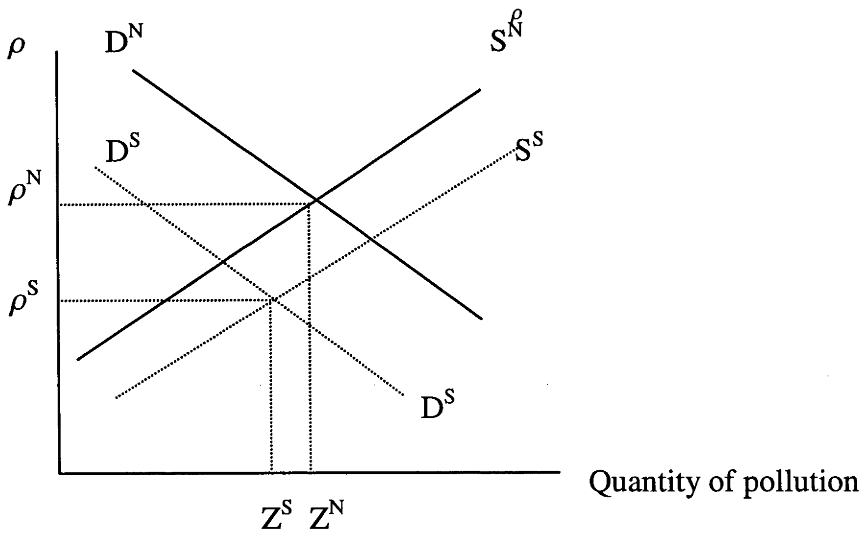
This is the inverse supply curve for pollution. It is upward sloping because consumers are willing to tolerate increased pollution if they are compensated with the income derived from higher pollution charges.

The demand for pollution (as an intermediate input into goods production) can be written as a decreasing function of ρ under suitable assumptions on technology. This simple framework can then be extended to two countries (North and South) that differ only in their endowment of human capital (as mark-up, or effective, labour). If North has a greater level of human capital, then the demand for pollution in North, N^D, is higher than in South (equation (2.5)) and the supply of pollution in North would be less than in South since North has a higher income. Under autarky, we can conclude that

$$\rho^N > \rho^S$$

That is, under autarky, the relative optimal pollution tax would be higher in North than in South. This creates incentives to trade. Under free trade, this model predicts that South should export relatively dirty goods and import relatively clean goods.

Figure 2.5 Trade patterns in ESGs: a supply and demand analysis



Source: Copeland and Taylor (1995).

Chichilnisky (1994) looks at North–South trade from the perspective of property rights but the result is also essentially in the spirit of the H–O theorem. The model assumes that North and South are identical in regard to standard H–O assumptions except that North has the institutions to control externalities optimally, while South has no such institutions. Chichilnisky defines comparative advantage in such a manner that region S is said to have a comparative advantage in the production of environmentally intensive goods, when for each price of environmental resource p_E the supply of environmental resource relative to other factors in region S is larger than the corresponding supplies in region N. The 'actual comparative advantage' is defined as the point where comparative advantage is the result of two well-defined property right regimes (North and South) so that all the externalities have been internalised. The 'apparent comparative advantage' is the result of an ill-defined property right regime so that some externalities are not internalised. The model predicts that South, with ill-defined property rights, will export more environmentally-intensive goods than North, with its well-defined property rights, despite the fact that 'actual comparative advantage' and 'apparent comparative advantage' are distinguished in the model.

Although Chichilnisky argues that her definition of comparative advantage is different from classical ones since the endowments of factors are price-dependent, so at different prices the countries can exhibit different H–O advantages (Chichilnisky: 858), the results are essentially in line with the predictions of the H–O theorem. Relaxing the assumption of fixed supply in the H–O framework has been an important focus of extensions of H–O theorem. As surveyed by Falvey (1994), however, under the assumption of variable factor supplies, the trade pattern can be explained in terms of differences in factor 'use'. The implications of variable factor supplies for the H–O theorem depend crucially on the sign of the relevant factor supply elasticities. If these elasticities are positive, as in the case of Chichilnisky's model, then the H–O theorem can simply be restated in terms of 'relative abundant utilisation'. It is not surprising that the results from Chichilnisky's model are essentially what the H–O theorem predicts. Once the institutional constraints are in place, the price of environmental resources is determined so the relative abundance of factor endowments is determined. Countries with ill-defined property rights for environmental resources tend to have relative abundant utilisation of environmental resources and will export more environmentally-intensive goods.

Chichilnisky's model can be analysed using Copeland and Taylor's (1995) supply and demand framework. Institutional failure in South leads to a perfectly elastic supply curve at $\rho^S = 0$ (Figure 2.5). North has a supply curve S^N with an autarky price $\rho^N > 0$. South will generate comparative advantages in the production of and exports of environmentally-intensive goods under free trade, and trade creates a pollution haven in South.

Markusen (1997) sets up a simple two-country computable equilibrium model in which countries are identical and each country has two industries, one competitive and the other experiencing increasing returns under conditions of imperfect competition and free entry by multinational firms. His model predicts that plants will migrate to regions with weaker environmental regulations when trade is liberalised.

Although general equilibrium models along the lines of the H–O theorem provide some interesting insights into the relationship between domestic environmental policies and trade patterns, they do not explain the existing empirical evidence satisfactorily. Why do these models fail to explain the empirical evidence?

At least two points need to be highlighted. First, the above extension of the H–O theorem to trade in ESGs is valid only to the extent that the five assumptions of the model are satisfied. Some of these assumptions are very restrictive when one takes into account the real-world situation. For example, the assumption of identical technology across countries may not be appropriate if looking at North–South problems. Perfect competition and identical preferences are also very restrictive assumptions. Second, most of the above theoretical models along the lines of the H–O theorem can only capture the static factor endowment effect and are therefore subject to Porter and van der Linde's (1995) criticism that technological innovation effects are not considered.

We now turn to another approach, the Heckscher–Ohlin model with Ricardian technology (H–O–R).

General equilibrium models (II): the Heckscher–Ohlin model with Ricardian technology

General equilibrium models of the kind discussed in the last section, are static in that they assume identical technology and production functions across countries. However, there are three ways to incorporate technology differences into the static H–O framework.

First, the assumption of identical technology can be relaxed in the basic H–O world.

Under Ricardo's framework, international differences in technology are not only allowed, but serve as the basis for explaining positions of comparative advantage. Empirically, since MacDougall's (1951) classic study, researchers have consistently found relative labour costs to be a powerful explanatory variable for trade flows. The many follow-up studies include Balassa (1963) and Golubad Hsieh (1995).[7] Since the 1960s trade theorists have been interested in modifying the H–O model to allow countries to differ in their prevailing states of technology. Jones (1970) provides a comprehensive theoretical account of technology differences under the H–O framework.

As surveyed by Falvey (1994), the effects of technology differences can be divided into two major categories, product-augmenting and factor-augmenting. Product-augmenting technology differences imply that one country can produce a larger output from the same factor inputs in a particular sector (or sectors) and the technology therefore acts very much like product price changes. Factor-augmenting technology differences imply that a factor (or factors) in one country is uniformly more productive than the same factor in the other, independent of the sector in which the factor is employed and this type of technology acts very much like factor endowment changes. If technology differences are purely factor-augmenting, the trade pattern might be explained in terms of 'effective' factor endowments. But to the extent that technology differences are product-augmenting, there are now two potential determinants of the pattern of trade. It is straightforward to apply this to analyse the relationship between environmental regulation and trade. If there is a factor-augmenting technology difference between the North and the South in which

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[7] See Obstfeld & Rogoff (1996).

the North possesses advanced technology, this may lead to production and export of more of pollution-intensive goods in the North.

The second approach is attributed to Davis (1995). It is now accepted as a matter of fact that empirically the Heckscher–Ohlin–Vanek (H–O–V) theorem performs 'horribly' with a success rate matched by a coin toss[8] and that the H–O–V framework does not incorporate the theoretical challenge of 'new trade theory'. Davis develops a model that allows for both Ricardian and Heckscher–Ohlin influences (termed the Heckscher–Ohlin–Ricardian model or H–O–R), providing a unified account of intra-industry and inter-industry trade. Intra-industry trade can arise even if returns to scale are constant and markets perfectly competitive. The model assumes there are two countries, One and Two, two factors, K (capital) and L (labour), three goods, X_1, X_2 and Y. The first two goods are perfectly competitive intra-industry goods and are capital-intensive relative to Y. Preferences are identical and homothetic. Technologies are assumed to be identical across countries in X_2 and Y, with a small Hicks-neutral productivity difference in X_1. Since there is an absolute technical advantage in the production of good X_1, only the technology of country One (which is assumed to have the superior technology in the production of X_1) will be used in production of this good.

The results are in sharp constrast with the H–O model. First, the H–O model simply predicts that a country exports the good that uses intensively its relatively abundant factor of production. The H–O–R model predicts that there are two possibilities. If country One is the labour-abundant country, but has an absolute advantage in the production of good X_1, it produces the world supply of that capital-intensive good, so

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[8] Trefler (1995: 1029).

must export it. Even if One is the capital-abundant country, since its factor endowment net of this may make it the 'labour-abundant' country in the residual, factor endowments are employed to produce the goods with common technologies. Labour-abundant country Two would then export capital-intensive good X_2. Second, in strong contrast to the H–O model, H–O–R predicts that even countries with identical endowment ratios may engage in substantial trade, namely, intra-industry trade.

Since a Ricardian element is brought into the H–O framework, absolute advantage becomes an important factor along with relative factor endowment in determining the pattern of trade. The H–O–R model has received strong empirical support recently. For example, Harrigan (1997), in an econometric study, finds that relative productivity which is in the spirit of Ricardian model, when combined with factor endowments, significantly improves the explanations for changing trade patterns. Trefler's (1995: 1029) empirical test also reveals that 'H–O–V is rejected empirically in favor of a modification that allows for home bias in consumption and international technology differences'.

Despite the advance in the theoretical modelling that incorporates Ricardian elements into the H–O framework, the literature on environmental regulation and the competitiveness debate has not so far been able to take advantage of this development.

Further, one has to recognise that both the first and second approaches treat technology differences as exogenously given and there is a lack of intertemporal dynamic determinants. The third approach is to model R&D and innovation as endogenous variables that interact with changes in environmental policy. The literature on the effects of environmental policy on growth is scant. Chapter 6 provides a model for R&D and innovation as endogenous variables interacting with changes in environmental policy.

This chapter has provided a brief review of the established empirical and theoretical literature on the trade effects of environmental policy and highlighted shortcomings in the existing literature. The next chapter presents an empirical analysis of the trade-environment nexus using time-series data and a trade-in-goods approach.

3

Trade in Environmentally Sensitive Goods: A Global Perspective[1]

Introduction

Widespread concern has been expressed recently about the relationship between the international competitiveness of ESGs and environmental regulations.[2] Does free trade with countries with lower environmental standards lead to a shift of production activity away from home countries with higher environmental standards to foreign countries? Will countries with higher standards be forced to lower their standards if capital and jobs also migrate to exploit lower environmental standards abroad (the so-called 'race to the bottom')?[3] Is it really the case that countries with lower environmental regulations increase their competitiveness in the production of ESGs? This last question receives considerable attention whenever countries are in the process of passing new pollution control measures.

As discussed in Chapter 2, one of the limitations of the existing empirical literature is that time-series patterns of trade in ESGs are seldom explored. This results in an incomplete picture of the changing pattern of export performance of ESGs over time. It is my belief that a complete picture of the changing pattern of export performance of ESGs over time is an essential starting point for any study on the debate on international trade, environmental regulation and the competitiveness of ESGs.

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[1] A version of this chapter has been accepted for publication in *World Development* (forthcoming).

[2] See Anderson and Blackhurst (1992), Dean (1992) and Low and Yeats (1992).

[3] See Bhagwati and Hudec (1996).

This chapter undertakes a preliminary analysis of the effects of environmental regulations on ESG trade by examining whether the pattern of export performance of environmentally sensitive goods has undergone systematic changes due to the introduction of stringent environmental standards in most developed countries in the 1970s and the 1980s. More precisely, I seek to examine whether countries with high export performance in ESGs in the 1960s became countries with low export performance in ESGs in the 1990s. A comprehensive dataset of trade flows of ESGs disaggregated to the four-digit level of the Standard International Trade Classification (SITC) is employed. The data relate to the period from 1965 through 1995 for 34 reporter countries. These 34 reporter countries include 25 OECD countries and some developing economies in East Asia and accounted for nearly 80 per cent of world exports of ESGs in 1995. These disaggregated trade data and the coverage of the reporter countries make it possible to obtain a good overview of the changing trade pattern of ESGs. The important empirical finding is that export performance of ESGs for most countries remained intact between the 1960s and the 1990s, despite the introduction of stringent environmental standards in most of the developed countries in the 1970s and 1980s.

I first look at the export performance of each ESG for each of the reporter countries in the initial year 1965, the first year in which data are available, and compare it with that in the end year 1995. Those countries which exported more than the world average of ESGs (i.e. those which had a revealed comparative advantage (RCA) index[4] greater than one) in 1965 achieved the same level of performance in 1995. Looking more closely at the year-to-year path of the RCA index of ESGs, I found that those commodities with either one or two years' high export performance (RCA

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[4] See the next section for the definition of the RCA index.

index greater than one) and those commodities with either 30 or 31 years' high export performance accounted for a large proportion of the exports of ESGs for most countries. Time-series patterns for the changing export performance of ESGs for some countries that claim to have higher environmental standards did not reveal a significant reduction in exports in the 1970s and 1980s. The results are quite robust in terms of both the weighted and the unweighted version of this trade pattern. This suggests that the pattern of export performance of ESGs has not undergone systematic change despite the introduction of stringent environmental standards in most developed countries in the 1970s and 1980s.

The following section provides a brief definition of ESGs and its relevant trade categories in terms of Standard International Trade Classification (SITC); section 3 discusses the dataset and methodology used in this study. Section 4 reports the results. Section 5 examines the robustness of the results and the final section presents a conclusion.

Definition of environmentally sensitive goods

There is no uniformly agreed definition of environmentally sensitive goods. Two approaches have been used to identify environmentally sensitive goods in the received literature.[5] The conventional approach has been to identify ESG sectors as those that have incurred high levels of abatement expenditure per unit of output in the United States and other OECD economies (see, for example, Robison 1988; Tobey 1990; and Low and Yeats 1992). The second approach is to select sectors which rank high on actual emissions intensity (emissions per unit of output) in the United States

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[5] See Mani and Wheeler (1997).

(see for example, Mani and Wheeler 1997). I adopt the conventional approach in this study. However, both approaches come up with similar environmentally sensitive sectors. Five sectors have typically emerged as leading candidates for environmentally sensitive sectors: iron and steel, non-ferrous metals, industrial chemicals, pulp and paper, and non-metallic products.

As defined in Low and Yeats (1992), environmentally sensitive goods include all four-digit products in SITC 67 (iron and steel), SITC 68 (non-ferrous metals) and SITC 69 (metal manufactures n.e.s.). Also included are all four-digit products in pulp and waste paper (251); organic chemicals (512); inorganic chemicals (513, 514); radioactive material (515); coal, petroleum chemicals (521); manufactured fertilisers (561); paper and paperboard (641); paper articles (642); veneers, plywood (631); wood manufactures n.e.s. (632); petroleum products (332); agricultural chemicals (599); and cement (661).[6] These industries incurred pollution abatement and control expenditures of approximately 1 per cent or more of the value of their total sales (1988). The highest expenditure:output ratio in 1988 was just over 3 per cent (cement) and the weighted average for all US industry was 0.54 per cent.

Data and methodology

This study uses a comprehensive dataset of annual trade flows (exports and imports) of ESGs disaggregated at the four-digit level of the Standard International Trade Classification (SITC) from 1965 to 1995 for 34 reporter countries.[7] These 34 reporter

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[6] Low and Yeats (1992). Tobey (1990) used a similar definition of environmentally sensitive goods.
[7] I focus on the SITC four-digit level rather than five-digit level because data for some commodities stop at the four-digit level without any further disaggregation. The data used in this study are taken from the United Nations COMTRADE database from International Economic Databank at the Australian National University.

countries accounted for nearly 80 per cent of world exports (and trade) of ESGs in 1995. They include 25 of the 29 OECD countries[8] as of May 1997, and major East Asian developing economies. There are 134 ESG commodities at the four-digit level. ESGs at the four-digit level include: chemical phosphatic fertiliser (SITC code 5612), newsprint paper (SITC code 6411), cement (SITC code 6612) and iron, steel wire products (SITC code 6731). There are 286,905 observations in total.

As is well known and discussed by Gagnon and Rose (1995),[9] the value of international trade flows has increased substantially in the last 40 years. This is partly a result of inflation, partly a result of real economic growth and partly a result of the increasing importance of trade relative to total output. In particular, a macroeconomic imbalance may result in substantial changes in net exports.

To abstract these effects from our data, the export-revealed comparative advantage (*XRCA*) index is used in this analysis. This *XRCA* index, introduced by Balassa (1989) in 1965, is defined as a country's share in the exports of a particular commodity divided by the share of that particular commodity in the world exports of manufactured goods, as follows

$$XRCA_i^k = \left(\frac{X_{iw}^k}{X_{iw}^l}\right) \div \left(\frac{X_{ww}^k}{X_{ww}^l}\right) \qquad (3.\ 1)$$

where $XRCA_i^k$ gives country *i*'s export revealed comparative advantage in industry *k*, X stands for exports, subscript *w* stands for world, superscript *k* represents industry *k*, and superscript *l* stands for total exports. This index has some limitations. It might not

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[8] Except Hungary, Czech Republic, Turkey and Iceland.

[9] Gagnon and Rose (1995) used similar methodology to test product cycle theory.

'reveal' the comparative advantage of a particular commodity especially when domestic or international distortions are present. However, as discussed in another paper by Balassa in 1987, other indices have their own disadvantages. For example, the net export index used by Balassa (1989) has the practical disadvantage of being affected by the idiosyncrasies of national import protection; in the case of intermediate products, net exports are influenced by demand for the purpose of further transformation in export production. Ballace, Forstner and Murray (1987) discuss the RCA index and find that, while cardinal measures of different RCA indices are highly inconsistent, both ordinal and dichotomous measures, and especially dichotomous measure, generate consistent results.[10] For the purposes of this study, I am interested only in the changing pattern of comparative advantage which can be adequately captured using dichotomous measures. Drysdale and Garnaut (1982) and Drysdale (1988) also provide extensive discussion of this and other related indices.

This *XRCA* index works reasonably well in terms of the above-mentioned data issue. Since it is an index, the inflation effect can be removed if it is an across-the-board increase in the prices of all commodities. By dividing exports of a particular commodity category by total manufactured exports, this index also takes into account

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[10] Ballace, Forstner and Murray (1987) discuss three trade-only RCA indices: (1) $T/XM_{ik} = T_{ik}/(X_{ik} + M_{ik})$; (2) $BAL_{ik} = X_{ik}/E(X_{ik})$; (3) $D\text{–}R_{ik} = ((T/XM_{ik}/T/XM_{im})\text{-}1)^{*}(\text{sign } T_{ik})$, where T is net trade (X - M), XM is total trade, i is the country, k is the commodity and m indicates the summation across all manufactured products. In the *BAL* index, $E(X_{ik}) = X_{wk}^{*}\ (X_{im}/X_{wm})$, where w indicates the summation across all countries. It represents the expected level of exports of the product from the country assuming the country's exports of the product are in proportion to the country's share of world exports of all manufactured products combined. *BAL* refers to the Balassa index (Balassa 1965). *D–R* index refers to Dongers and Riedel (1977). For *T/ XM*, see UNIDO (1982). There are three interpretations of these RCA indices. The traditional interpretation of RCA indices is that the index *quantifies* the commodity-specific degree of comparative advantage enjoyed by one country *vis à vis* any other country. The second interpretation is that these indices provides a commodity-specific ranking of countries by degree of comparative advantage. The third provides a *demarcation* between countries that enjoy a comparative advantage in a particular commodity and those countries that do not. These three alternatives are referred to as *cardinal*, *ordinal* and *dichotomous* measures, respectively.

macroeconomic trade balance effects. For instance, a 1 per cent growth in exports spread uniformly across all goods (for example, when domestic savings are greater than domestic investment) will not affect the level of this index. Furthermore, by dividing a country's export sectoral share of a particular commodity category by the same sectoral share in the world exports of manufactured goods, a general increase or decrease in world exports of a particular commodity (growth effect) will not change the level of this index either. This is particularly useful since the share of ESG exports to total exports has declined from 21.7 per cent in 1965 to 16.9 per cent in 1995 (Table 3.1).

Table 3.1 Exports of ESGs and their importance in world trade: cross-section and time series

	Europe OECD (18) countries	North America	Oceania	Northeast Asia	Southeast Asia	Other	World
Market shares of total exports by region (%)							
1965	45.1	20.8	2.3	6.7	2.5	22.7	100
1975	43.8	17.0	1.7	9.3	2.5	25.6	100
1985	42.4	17.5	1.6	15.6	3.8	19.1	100
1995	43.7	17.3	1.3	19.4	6.6	11.6	100
Shares of ESGs to total exports (%)							
1965	24.4	20.3	9.2	23.1	18.1	18.8	21.7
1975	24.5	17.2	15.1	23.6	17.8	16.1	20.7
1985	23.5	16.3	17.6	13.4	19.1	22.9	20.3
1995	18.7	16.5	20.2	11.3	11.9	22.6	16.9
Market shares of ESG exports by region (%)							
1965	50.6	19.5	1.0	7.1	2.1	19.7	100
1975	52.0	14.1	1.3	10.6	2.1	19.9	100
1985	49.1	14.1	1.4	10.3	3.6	21.6	100
1995	48.4	16.9	1.6	13.0	4.7	15.5	100

Note: Europe OECD includes 18 of the 22 European OECD countries (Finland, Greece, Ireland, the Netherlands, Poland, Sweden, United Kingdom, Austria, France, Italy, Belgium, Luxemburg, Portugal, Switzerland, Denmark, Germany, Norway and Spain) but not Hungary, Turkey, Czech Republic and Iceland, as of May 1997. North America refers to the US, Canada and Mexico. Northeast Asia includes Japan, Korea, Taiwan, China and Hong Kong. Southeast Asia includes Thailand, Malaysia, the Philippines, Indonesia and Singapore. Oceania includes Australia, New Zealand and Papua New Guinea. ESGs refers to environmentally sensitive goods.
Source: Author's calculations on the basis of United Nations COMTRADE database, International Economic Databank, Australian National University.

For reasons that will shortly become clear, a normalisation is used for the commodity trade share. This measures the relative importance of a particular commodity trade share in the trade of total ESGs at a particular point in time, as follows:

$$S_{it} = \frac{1}{2} \bullet \left(\frac{X_{it}}{X_{et}} + \frac{M_{it}}{M_{et}} \right) \bullet 100 \qquad (3.2)$$

where *i* refers to a particular commodity category within ESGs, *t* refers to a point in time and *e* indicates total ESGs. The sum of any time period over all ESGs is 100, and S_{it} is a percentage measure.

This dataset will be analysed from the following four perspectives. Changes in the dichotomous measures of the *XRCA* index between the beginning and the ending period of the sample will be examined first. We would like to see by what percentage the export flows of ESGs change in 1995 compared with those in 1965 for each of the reporter countries. One would expect that those commodities with a high export performance at the beginning of the sample period will become less competitive at the end of the sample period if the claim that stringent environmental standards reduce 'international competitiveness' holds.

A second and more rigorous statistical test of the association between the 1965 series and the 1995 series is performed to determine whether there is any association between export performance of ESGs in the beginning and end years. Although a few tests for association are available, Kendall's tau-b[11] was chosen. This test ranks the *XRCA* index for each year and calculates the test statistic based on the number of concordant and discordant pairs of observations. Kendall's tau-b is similar to a gamma test but has the advantage that it also takes into account the tied pairs (that is, pairs of observations that have equal values of X or equal values of Y).[12]

As a third step in this analysis, histograms for each reporter country based on the number of years each reporter country has 'revealed comparative advantage' (or 'specialisation' with an *XRCA* greater than 1 are used to look at the ESG export performance in the intervening years. Of course, there are two different ways to look at this. The first counts the number of commodities that fall into each of the zero and 31 year frequencies and reports this as a percentage of the total number of commodities. The other takes the normalised trade share of each commodity in a particular year (1990 in this exercise) as the weight, and reports this percentage. The latter is generally supposed to convey more information. However, as an alternative way to look at this issue, the former will be discussed in the section on robustness. If environmental standards have significant effects on trade flows of ESGs, then one might expect there to be many fluctuations of these histograms, indicating that many ESGs have changed their export performance position.

Fourthly, an alternative perspective is provided by looking at the export performance of ESGs in the intervening years. For this purpose, a time-series pattern of export performance of ESGs is calculated. The indicator used here is the percentage trade

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[11] The formula for Kendall's tau-b is as follows: tau-b = $(P-Q)/((w_r w_c)^{1/2})$, where $P = \sum_i \sum_i n_{ij} A_{ij}$ (twice the number of concordances), $Q = \sum_i \sum_i n_{ij} D_{ij}$ (twice the number of disconcordances), $A_{ij} = \sum_{k>i} \sum_{l>j} n_{kl} + \sum_{k<i} \sum_{l<j} n_{kl}$, $D_{ij} = \sum_{k>i} \sum_{l<j} n_{kl} + \sum_{k<i} \sum_{l>j} n_{kl}$, $w_r = n^2 - \sum_i n_{i.}^2$ and $w_c = n^2 - \sum_i n_{.j}^2$. See Kendall and Stuart (1979).

[12] The Spearman correlation test statistic does not take tied pairs into account.

share of those ESGs that indicated a 'specialisation' in total ESGs trade for each year and each country. Since a dichotomous measure can be assigned to each commodity at a particular point in time, the normalised trade share of those commodities (within the ESG group) is summed to provide a percentage share of the normalised trade of all ESGs. If the above histogram does not convey sufficient information about the locus of the changing share of one country's competitive ESGs, this time-series pattern then offers a unique picture to look at the export performance of ESGs for a selected country over time. This indicator therefore can be expressed as

$$C_{it} = \left\{ \sum^{k} S_{it}^{k} \middle| XRCA_{it}^{k} \geq 1 \right\} \qquad (3)$$

where C_{it} is the competitive indicator for country *i* at time *t*. *k* denotes commodity (ESGs). S_{it} denotes shares of commodity *k* in country *i*'s total trade at time *t*.

Results

Table 3.2 shows the breakdown of dichotomous measures of the *XRCA* index between the beginning (1965) and the end of the period (1995). This is the weighted version of the breakdown of the *XRCA* index between 1965 and 1995.

These tables are reported using the following matrix:

	1995 N	1995 S	Total
1965 N	A_{11}	A_{12}	A_1
1965 S	A_{21}	A_{22}	A_2
Total	A_3	A_4	100

where

A_1 = Percentage of normalised trade flows of ESGs that were not specialised in 1965.

A_2 = Percentage of normalised trade flows of ESGs that were specialised in 1965.

A_3 = Percentage of normalised trade flows of ESGs that were not specialised in 1995.

A_4 = Percentage of normalised trade flows of ESGs that were specialised in 1995.

A_{11} = Percentage of normalised trade flows of ESGs that were not specialised in 1965 or in 1995.

A_{12} = Percentage of normalised trade flows of ESGs that were not specialised in 1965 but became specialised in 1995.

A_{21} = Percentage of normalised trade flows of ESGs that were specialised in 1965 but became non-specialised in 1995.

A_{22} = Percentage of normalised trade flows of ESGs that were specialised both in 1965 and in 1995.

'N' stands for 'non-specialisation' where the *XRCA* index is less than one while 'S' refers to 'specialisation' where the *XRCA* index greater than one. It is a dichotomous measure in the sense that each commodity at a particular point in time is either in the position of 'S' or 'N'. '1965 N' therefore represents those commodities that did not have 'revealed comparative advantage' in 1965 while '1965 S' represents those commodities that had 'revealed comparative advantage' in 1965.

The same logic applies to both '1995 N' and '1995 S'. Since this is the weighted version (using commodity shares in the ESG group in 1990 as the weight) of the *XRCA* dichotomy, the number in the tables represents the percentage of trade flows rather than the percentage of the number of commodities. These trade flow percentages of ESGs should sum to 100 at any given point in time. The fourth column of each of the two-way tables is the breakdown of the 1965 ESG trade flows while the fourth row of each two-way table is the 1995 breakdown.

Table 3.2 Breakdown of two-way tables: selected countries

Australia

	1995 N	1995 S	Total
1965 N	38.1	11.1	49.2
1965 S	10.1	40.7	50.8
Total	48.2	51.9	100

Kendall's tau-b: 0.27
P-value: 0.0001
No. of ESGs:133

Austria

	1995 N	1995 S	Total
1965 N	20.0	17.1	37.1
1965 S	12.2	50.7	63.0
Total	32.2	67.8	100

Kendall's tau-b: 0.34
P -value: 0.0001
No. of ESGs:133

Belgium-Luxembourg

	1995 N	1995 S	Total
1965 N	18.8	32.0	50.8
1965 S	6.8	42.4	49.2
Total	25.6	74.4	100

Kendall's tau-b: 0.39
P -value: 0.0001
No. of ESGs:134

Brazil

	1995 N	1995 S	Total
1965 N	25.8	46.8	72.5
1965 S	1.6	25.9	27.5
Total	27.3	72.7	100

Kendall's tau-b: 0.25
P -value: 0.0001
No. of ESGs:130

Canada

	1995 N	1995 S	Total
1965 N	31.2	23.3	54.5
1965 S	5.8	39.8	45.6
Total	37.0	63.1	100

Kendall's tau-b: 0.29
P -value: 0.0001
No. of ESGs:125

Chile

	1995 N	1995 S	Total
1965 N	42.9	12.4	55.4
1965 S	0.0	44.6	44.6
Total	43.0	57.0	100

Kendall's tau-b: 0.27
P -value: 0.0001
No. of ESGs:129

China

	1995 N	1995 S	Total
1965 N	57.0	8.4	65.4
1965 S	17.4	17.1	34.6
Total	74.4	25.6	100

Kendall's tau-b: 0.15
P -value: 0.01
No. of ESGs: 134

Denmark

	1995 N	1995 S	Total
1965 N	38.6	19.4	58.0
1965 s	7.5	34.5	42.0
Total	46.1	53.9	100

Kendall's tau-b: 0.40
P -value: 0.0001
No. of ESGs:134

Finland

	1995 N	1995 S	Total
1965 N	31.2	20.6	51.8
1965 S	2.7	45.6	48.2
Total	33.8	66.2	100

Kendall's tau-b: 0.30
P-value: 0.0001
No. of ESGs:132

France

	1995 N	1995 S	Total
1965 N	26.7	22.5	49.2
1965 S	19.3	31.5	50.8
Total	46.0	54.0	100

Kendall's tau-b: 0.15
P-value: 0.0128
No. of ESGs:133

Greece

	1995 N	1995 S	Total
1965 N	45.1	26.9	72.0
1965 S	7.7	20.4	28.0
Total	52.7	47.3	100

Kendall's tau-b: 0.24
P-value: 0.0002 No. of ESGs:128

Hong Kong

	1995 N	1995 S	Total
1965 N	59.1	17.9	77.0
1965 S	4.0	17.5	21.5
Total	63.1	35.4	98

Kendall's tau-b: 0.50
P-value: 0.0001 No. of ESGs:106

Indonesia

	1995 N	1995 S	Total
1965 N	45.5	49.8	95.3
1965 S	1.9	2.8	4.7
Total	47.4	52.6	100

Kendall's tau-b: 0.20
P-value: 0.005 No. of ESGs:128

Ireland

	1995 N	1995 S	Total
1965 N	37.7	46.8	84.5
1965 S	9.1	6.4	15.5
Total	46.8	53.2	100

Kendall's tau-b: 0.21
P-value: 0.002 No. of ESGs:132

Italy

	1995 N	1995 S	Total
1965 N	41.7	14.6	56.3
1965 S	10.8	32.9	43.7
Total	52.5	47.5	100

Kendall's tau-b: 0.38
P-value: 0.0001 No. of ESGs:134

Japan

	1995 N	1995 S	Total
1965 N	52.4	8.1	60.5
1965 S	17.7	21.8	39.5
Total	70.1	29.9	100

Kendall's tau-b: 0.31
P-value: 0.0001 No. of ESGs:134

Korea

	1995 N	1995 S	Total
1965 N	40.6	42.1	82.7
1965 S	8.2	9.1	17.3
Total	48.8	51.2	100

Kendall's tau-b: 0.26
P-value: 0.0001 No. of ESGs:133

Malaysia

	1995 N	1995 S	Total
1965 N	56.4	20.6	77.0
1965 S	3.5	19.5	23.0
Total	59.9	40.1	100

Kendall's tau-b: 0.38
P-value: 0.0001 No. of ESGs:133

Mexico

	1995 N	1995 S	Total
1965 N	46.3	15.8	62.0
1965 S	15.8	22.2	38.0
Total	62.0	38.0	100

Kendall's tau-b: 0.28
P-value: 0.0001 No. of ESGs:134

Netherlands

	1995 N	1995 S	Total
1965 N	22.1	16.4	38.4
1965 S	0.9	60.7	61.6
Total	23.0	77.0	100

Kendall's tau-b: 0.40
P-value: 0.0001 No. of ESGs:133

New Zealand

	1995 N	1995 S	Total
1965 N	31.2	45.2	76.4
1965 S	0.3	23.3	23.6
Total	31.5	68.5	100

Kendall's tau-b: 0.44
P-value: 0.0001 No. of ESGs:131

Norway

	1995 N	1995 S	Total
1965 N	26.5	15.3	41.8
1965 S	21.2	37.0	58.2
Total	47.7	52.3	100

Kendall's tau-b: 0.23
P-value: 0.0001 No. of ESGs:131

Philippines

	1995 N	1995 S	Total
1965 N	62.5	23.3	85.8
1965 S	10.0	4.3	14.2
Total	72.5	27.5	100

Kendall's tau-b: 0.22
P-value: 0.0027
No. of ESGs:124

Poland

	1995 N	1995 S	Total
1965 N	18.6	31.1	49.7
1965 S	13.1	37.2	50.3
Total	31.7	68.3	100

Kendall's tau-b: 0.20
P-value: 0.0005
No. of ESGs:134

Portugal

	1995 N	1995 S	Total
1965 N	52.5	25.8	78.3
1965 S	3.2	18.5	21.7
Total	55.7	44.3	100

Kendall's tau-b: 0.37
P-value: 0.0001
No. of ESGs:133

Singapore

	1995 N	1995 S	Total
1965 N	60.4	16.8	77.2
1965 S	17.8	5.0	22.8
Total	78.2	21.8	100

Kendall's tau-b: 0.15
P-value: 0.0123
No. of ESGs:131

Spain

	1995 N	1995 S	Total
1965 N	42.8	40.0	82.8
1965 S	7.6	9.6	17.2
Total	50.4	49.6	100

Kendall's tau-b: 0.21
P-value: 0.0005
No. of ESGs:134

Sweden

	1995 N	1995 S	Total
1965 N	28.4	17.1	45.5
1965 S	6.0	48.5	54.5
Total	34.4	65.6	100

Kendall's tau-b: 0.50
P-value: 0.0001
No. of ESGs:132

Switzerland

	1995 N	1995 S	Total
1965 N	37.9	21.5	59.3
1965 S	0.5	40.2	40.7
Total	38.4	61.6	100

Kendall's tau-b: 0.49
P-value: 0.0001
No. of ESGs:133

Taiwan

	1995 N	1995 S	Total
1965 N	45.9	37.7	83.6
1965 S	14.3	2.1	16.4
Total	60.1	39.9	100

Kendall's tau-b: 0.13
P-value: 0.0337
No. of ESGs:134

Thailand

	1995 N	1995 S	Total
1965 N	67.9	19.9	87.9
1965 S	1.7	10.4	12.1
Total	69.6	30.4	100

Kendall's tau-b: 0.38
P-value: 0.0001
No. of ESGs:131

United Kingdom

	1995 N	1995 S	Total
1965 N	42.5	31.6	74.2
1965 S	5.3	20.6	25.9
Total	47.8	52.2	

Kendall's tau-b: 0.39
P-value: 0.0001
No. of ESGs:134

United States

	1995 N	1995 S	Total
1965 N	41.4	14.2	55.6
1965 S	14.3	30.1	44.4
Total	55.8	44.2	100

Kendall's tau-b: 0.39
P-value: 0.0001
No. of ESGs:134

Venezuela

	1995 N	1995 S	Total
1965 N	27.9	67.7	95.7
1965 S	1.8	2.2	4.0
Total	29.8	69.9	100

Kendall's tau-b: 0.04
P-value: 0.58
No. of ESGs:130

Source: Author's calculations on the basis of United Nations COMTRADE database, International Economic Databank, Australian National University.

For example, in the case of Australia, 49.2 per cent of the normalised trade flows of ESGs were in a position of 'non-specialisation' while 50.8 per cent of the normalised trade flows of ESGs were in a position of 'specialisation' in 1965. Among the 49.2 per cent of the normalised trade flows of ESGs which were in a position of 'non-specialisation' in 1965, 38.1 per cent remains in a position of 'non-specialisation' in 1995 while 11.1 per cent switch to a position of 'specialisation'. The same logic applies to the column-wise explanation.

If stringent environmental standards do hurt those countries with higher environmental standards (mostly developed countries) and benefit those countries with lower environmental standards (mostly developing countries), then one would expect a significant changes in the export performance of ESGs across countries. In other words, the export performance of the ESGs of developing countries would increase while that of developed countries would decrease. However, a striking feature of this table is that trade volumes that move from a 'specialisation' position to a 'non-specialisation' position account for no more than 15 per cent of the ESG trade volumes for the majority countries except for China, France, Japan, Norway and Singapore, whose percentage is about 20.[13]

Further, taking into account those trade volumes that move from a position of 'non-specialisation' to a position of 'specialisation', one can see that these trade volumes always exceed trade volumes that move from a 'specialisation' position to a 'non-specialisation' position with the exceptions of Japan, Norway and China.[14] Even in the case of Japan, Norway and China, this difference is very small, 9.57 per cent, 5.95 per cent and 9.01 per cent, respectively. It becomes clear that the pattern of export

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[13] Mexico is on the margin, i.e. 15.75 per cent.

[14] The United States is on the margin with 14.34 per cent to 14.16 per cent.

performance of ESGs is quite persistent in the sample period. Those commodities which did not display much 'revealed comparative advantage' at the beginning of the sample period tend to remain in a position of 'non-specialisation', while those commodities which had a 'revealed comparative advantage' at the beginning of the sample period remain in a position of 'specialisation'.

There are two exceptions, Brazil and Venezuela. The pattern of ESG export performance in these two countries changed dramatically between 1965 and 1995. In Brazil, 72.5 per cent of the normalised trade flows of ESGs were in a position of 'non-specialisation' while 27.5 per cent of the normalised trade flows of ESGs were in a position of 'specialisation' in 1965. In 1995, 72.7 per cent of the normalised trade flows of ESGs were in a position of 'specialisation' while 27.3 per cent of the normalised trade flows of ESGs were in a position of 'non-specialisation'. In the case of Venezuela, 95.7 per cent of the normalised trade flows of ESGs were in a position of 'non-specialisation' while 4.0 per cent of the normalised trade flows of ESGs were in a position of 'specialisation' in 1965. In 1995, 69.9 per cent of the normalised trade flows of ESGs were in a position of 'specialisation' while only 29.8 per cent of the normalised trade flows of ESGs were in a position of 'non-specialisation'.

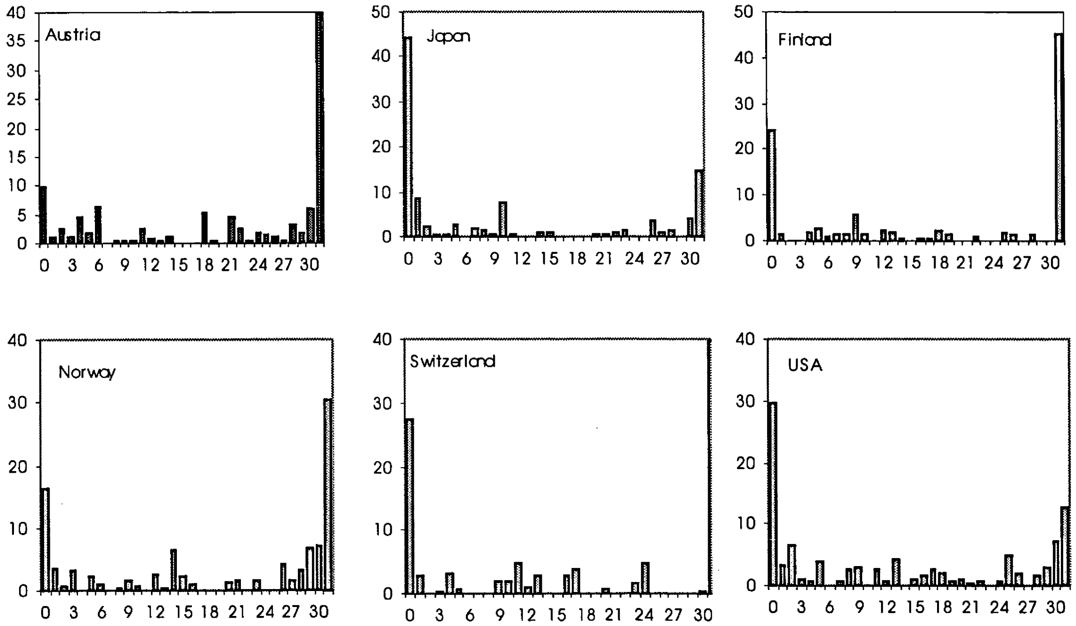
Measures of association using Kendall's tau-b test statistic also convey the economic message that there is a strong association between the export performance of ESGs between 1965 and 1995. The p-value shows that the null hypothesis that the two series are distributed independently can be rejected at a significance level of 1 per cent for most countries except China (1.02%), France (1.28%), Singapore (1.23%), Taiwan (3.37%) and Venezuela (58.1%). This result is presented beneath the two-way tables for each country in Table 3.2. Note that Kendall's tau-b ranges from -1 to +1 and the nominator is the difference between twice the number of concordances and twice the number of disconcordances. If this difference is not very large, Kendall's tau-b coefficient can be very low. This does not necessarily mean that the correlation between the two series is weak.

These two-way tables and their statistical tests suggest that those commodities with a high export performance at the beginning of the sample period remain competitive at the end of the sample period for most countries.

Figure 3.1 provides a histogram of *years in 'specialisation'* for selected countries that claim to have higher environmental standards (see Appendix 3 for results of other countries). The data are first classified by reporter and commodity. The number of *years in 'specialisation'* is then counted for each commodity. Since there are 31 years of observations in total, a sub-group that was in '*specialisation*' for each of the 31 years then is put to the extreme right of the histogram while a sub-group that was not in '*specialisation*' for each of the 31 years is put to the extreme left of the histogram. These are the weighted versions of the histogram in the sense that it is the normalised trade volume rather than the number of commodities that is put into each cell.

If stringent environmental standards do have a significant impact on the international competitiveness of ESGs, one would expect that many goods are not in consistent 'specialisation' or 'non-specialisation'. For most countries, one can see a bimodal breakdown of the composition of trade in ESGs, especially for OECD countries, indicating that most trade in ESGs is accounted for by goods in consistent 'specialisation' or 'non-specialisation'.

Figure 3.1 Histograms of years in 'specialisation' of ESGs for selected countries: 1965–95

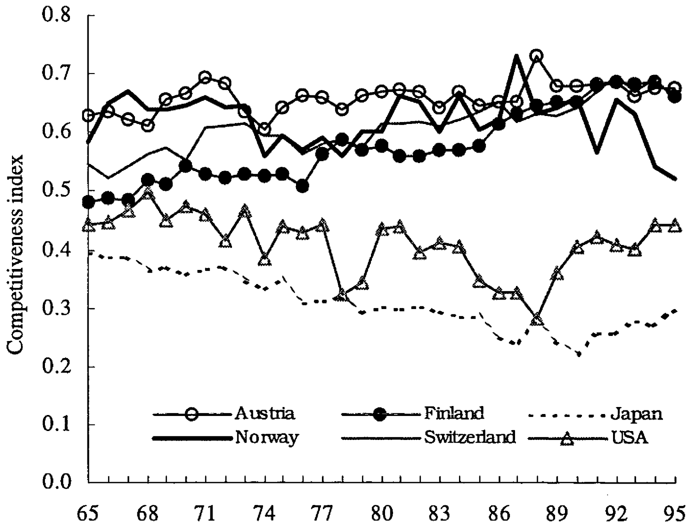


Notes: The horizontal axis denotes number of years in specialisation. The vertical axis denotes percentage trade share in total ESGs.
Source: Author's calculations on the basis of the United Nations COMTRADE database from International Economic Data Bank, Australian National University.

For developing countries, one can see the same results with the exceptions of Brazil, Mexico, Philippines and Venezuela. Overall, these histograms also reveal that export performance of ESGs for most countries is quite persistent. As these histograms do not consider the sequencing of export performance of ESGs, an alternative way to look at the ESG export performance in the intervening years is necessary.

Figures 3.2 shows the time-series pattern of the share of the normalised trade volume of those ESGs with an *XRCA* index greater than one relative to total ESG trade for some selected countries that claim to have higher environmental standards. This simple figure reveals a more striking result. The share of the normalised trade volume of those ESGs with the *XRCA* index greater than one relative to total ESG trade did not decrease over time for most countries, except Japan.

Figure 3.2 Time-series pattern of the overall competitiveness of ESGs for selected countries



Source: Author's calculations on the basis of the United Nations COMTRADE database from International Economic Data Bank, Australian National University.

If the sample period is then divided into two sub-periods, before and after the end of the 1980s, for Japan and the United States, one can see that after a slow decrease in competitiveness of ESGs in the first period, there was a stark increase in competitiveness of ESGs in the second period. This is an interesting story that requires more theoretical explanation along with an examination of the overall export performance of ESGs over time.

The above analysis suggests that the export performance of ESGs is persistent throughout the sample period despite the introduction of stringent environmental standards by the industrialised countries two decades ago. The claim that higher environmental standards reduce the 'international competitiveness' of ESGs cannot be justified in the light of the available data.

Robustness

The dataset used in this study is comprehensive in the sense that it covers nearly 80 per cent of the world exports of ESGs. It is important to test the robustness of the results to determine the extent to which the results are affected by the way we look at these data.

As a check on the robustness of my findings, the data are smoothed using a three-year average in order to reduce the influence of any irregular variations in a particular year. Two period averages, 1965–67 and 1993–95, have been chosen as representative of the 1960s and the 1990s. A similar breakdown of the two-way tables is then calculated both for the weighted and the unweighted trade volume of each country. The finding that trade volumes that move from a position of ‘specialisation’ to a position of ‘non-specialisation’ account for no more than 15 per cent of the ESG trade volumes for the majority of countries is even more starkly apparent. France, with 19.3 per cent previously, had a 13.09 per cent downturn in this three-year average version. The maximum percentage downturn is 18.97 per cent (Singapore) in this version compared with 21.20 per cent (for Norway, which recorded 17.09 per cent in the three-year average) in the previous version.

The unweighted two-way tables are also calculated for each of the countries and the findings remain unchanged. Those commodities that move from a position of ‘specialisation’ to a position of ‘non-specialisation’ account for a small proportion of the ESG trade (less than 20 per cent) for the majority of countries.

To check the robustness of these results using the dichotomous measure, I take an approach suggested by Gagnon and Rose (1995). To eliminate small deviations from one in the *XRCA* index, ESGs are classified into categories: (a) those with a value of *XRCA* greater than one standard deviation above one, 'specialisation'; (b) those with a value of *XRCA* index within a standard deviation of one, 'balance'; (c) those with a value of *XRCA* index at least one standard deviation below one, 'non-specialisation'; where the standard deviation is computed for each commodity's *XRCA* time series. This categorisation is then applied to the first and last years of the data. Using the normalised trade volume computed earlier as the weight, we obtain the weighted 'standardised' version of the two-way tables.

The result shows that the majority of the ESGs commodities that have the status of 'specialisation', 'balance', or 'non-specialisation' in the first year remain in the same position in the last year for all the countries of interest. Those ESGs that switch their position from 'specialisation' in the first year to 'balance' or 'non-specialisation' in the last year again account for no more than 15 per cent of the total ESG trade volume for most countries except Japan, Mexico, France and Poland. If one takes account of those ESGs that switch their positions from 'balance' in the beginning year to 'non-specialisation' in the final year, the ESGs that show a decline in their competitiveness still account for less than 15 per cent for the majority of the countries except Japan, Mexico, France, Poland, Norway and China, which have a reduction of around 20 per cent. This result is quite consistent with the result obtained from the simple dichotomous measures of the two-way tables.

Another check on the robustness of this finding is to calculate the unweighted version of the histogram of *years in 'specialisation'* for each country. Instead of using the normalised trade volume that corresponds to the cells they belong to in the histogram, the number of commodities is used in the calculation of cell entry. The results also show a bimodality for most countries.

One caveat is in order. While the *XRCA* index can be distorted by domestic or international protection, international protection may be more significant than domestic protection for exports of ESGs. In either case, this distortion would underestimate the *XRCA* index especially for developed countries whose average tariff levels are relatively lower than those of developing countries. This will lead to an underestimation of the percentage share of those commodities with a downturn from a position of 'specialisation' to 'non-specialisation'.

But if one looks at the changing pattern of those trade volumes that move from 'non-specialisation' to 'specialisation', these trade volumes always exceed trade volumes that move from 'specialisation' to 'non-specialisation' for the majority of the countries except for Japan, Norway and China, as discussed in the fourth section. This finding can thus be considered to be even more robust.

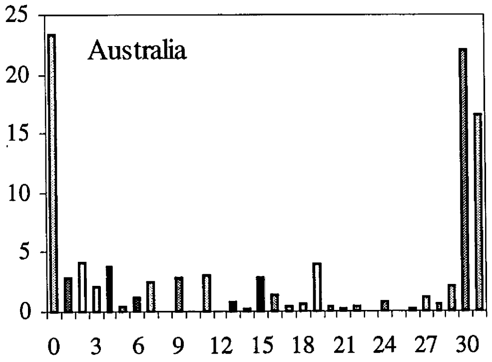
Conclusion

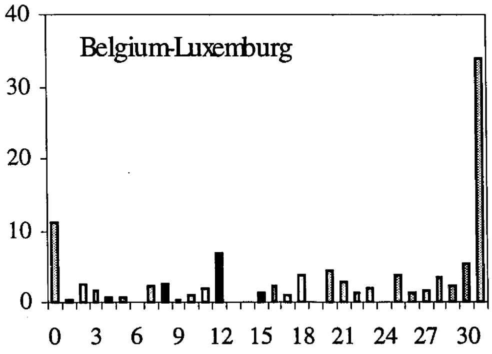
This chapter has examined whether the pattern of export performance of environmentally sensitive goods underwent systematic changes in the period between the 1960s to the 1990s. A comprehensive dataset of trade flows of ESGs disaggregated to the four-digit level of the Standard International Trade Classification (SITC), from 1965 to 1995 for 34 reporter countries is employed. These 34 reporter countries accounted for nearly 80 per cent of world exports of ESGs in 1995. It is therefore to be expected that this analysis will provide a full picture of the changing performance of ESGs over time. Two different means to break down the two-way tables of export performance of ESGs, using a histogram and time-series pattern, have been employed to examine the pattern of export performance of ESGs between the beginning (1965) and end year (1995), as well as in the intervening years.

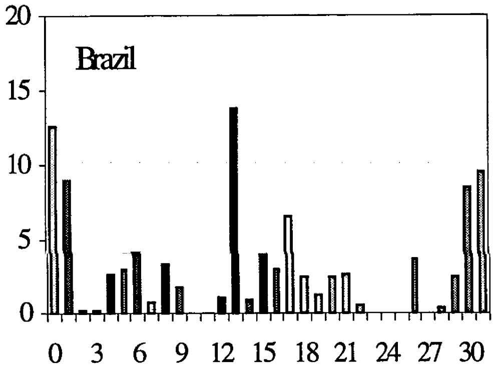
The important empirical finding is that the export performance of ESGs for most countries remained unchanged between the 1960s and the 1990s despite the introduction of stringent environmental standards in most of the developed countries in the 1970s and the 1980s. This result suggests that the claim that higher environmental standards reduce the 'international competitiveness' of ESGs cannot be justified easily, at least on the basis of this examination of the data. Of course, there may be other potential explanations for these empirical results. For example, it could be that the environmental standards actually adopted were not implemented effectively and did not, therefore, affect producer's behaviors and trade patterns. If this were so, it is difficult to understand why there has been so much attention focused on the issue of environmental standards worldwide. The more plausible explanation is, then, that there were some off-setting changes, such as through the adoption of new technologies to alleviate the impact of environmental controls, as suggested by Berman and Bui (1998). We shall come to this argument later in Chapter 6 and 7.

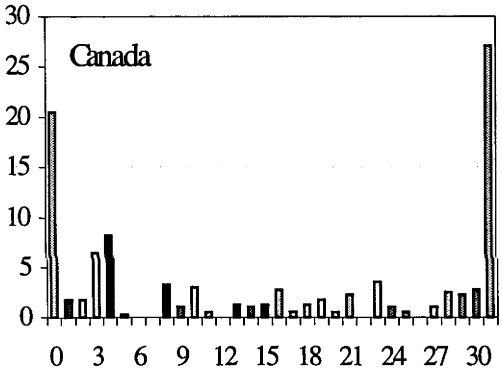
Since the relationship between environmental standards and international competitiveness has been treated as mutually exclusive theoretically (Pething 1976; McGuire 1982; Palmer, Oates and Portney 1995), the persistence of ESG export performance deserves closer scrutiny. The next chapter will provide a different perspective using an alternative approach, the factor-content-of-trade approach, to explore whether the net export content of environmental factor services for most countries underwent systematic changes in the last three decades.

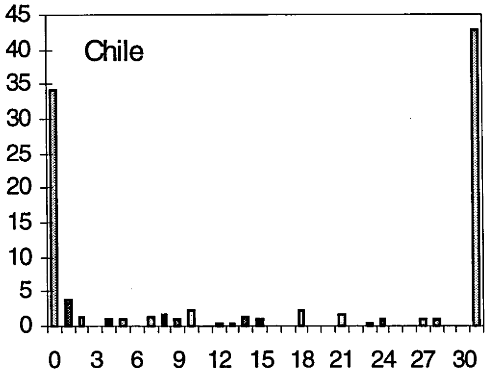
Appendix 3 Histograms of years in 'specialisation' of ESGs for selected countries: 1965–95 (continued)

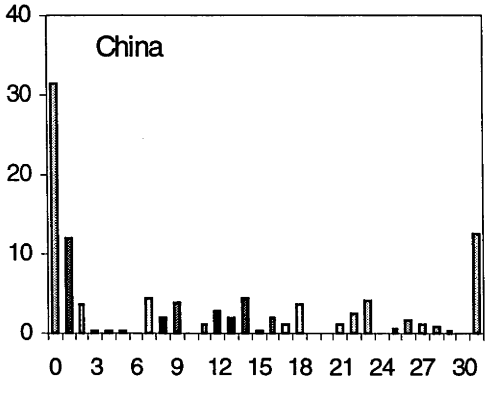


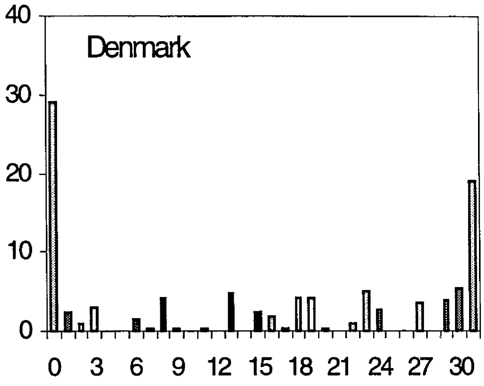








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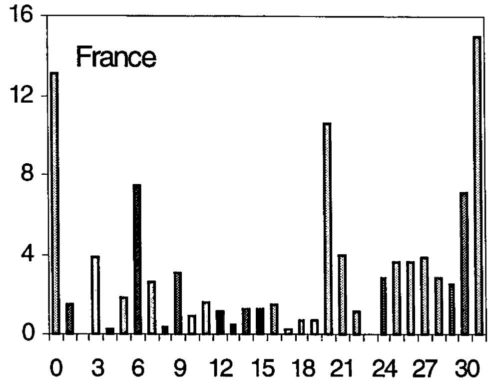
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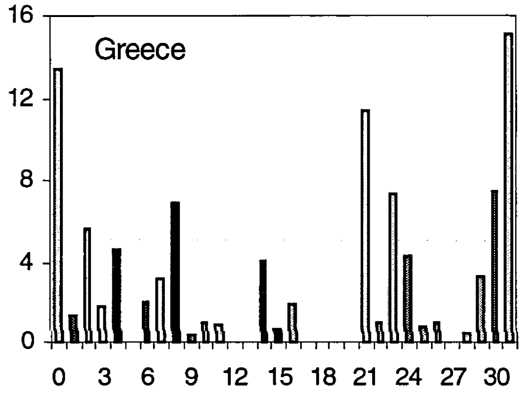
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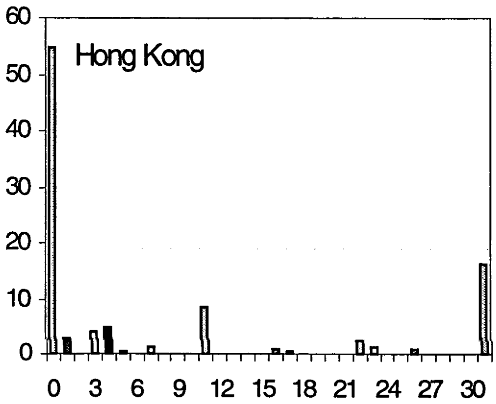
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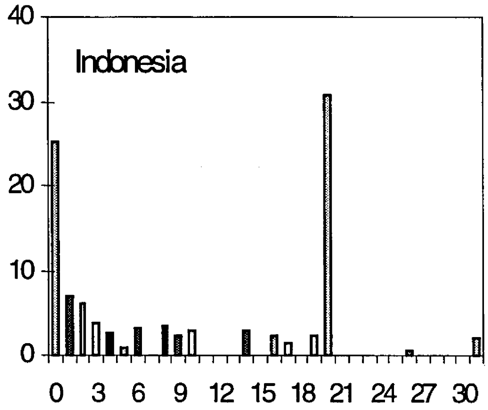
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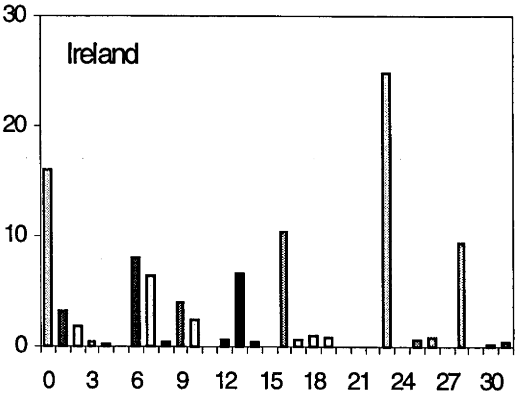
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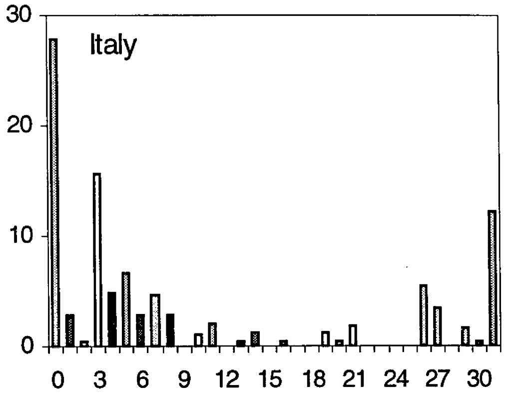
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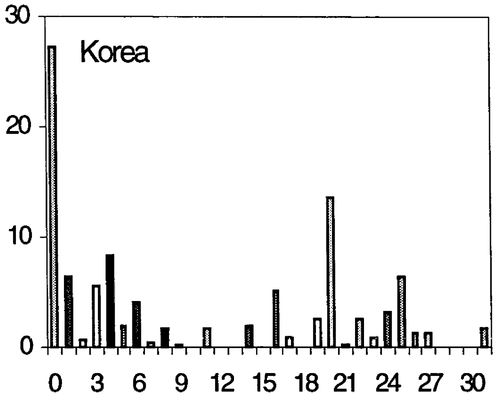
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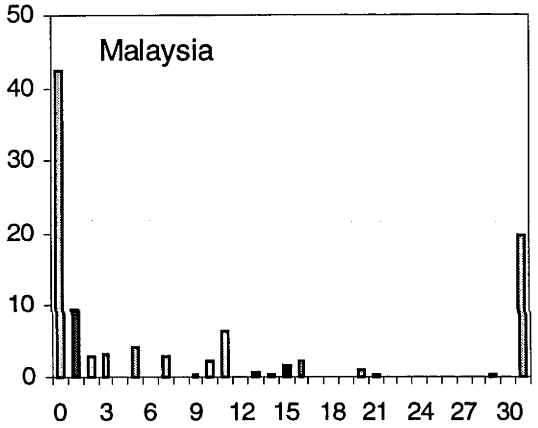
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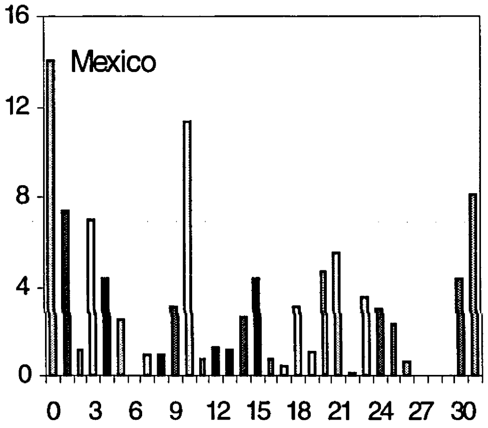
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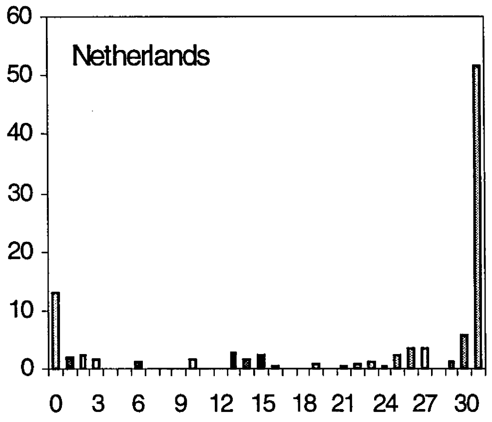
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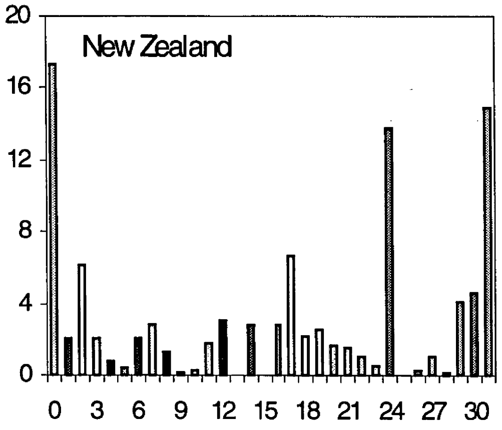
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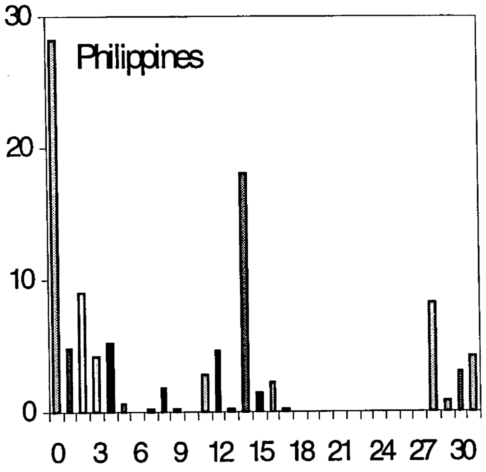
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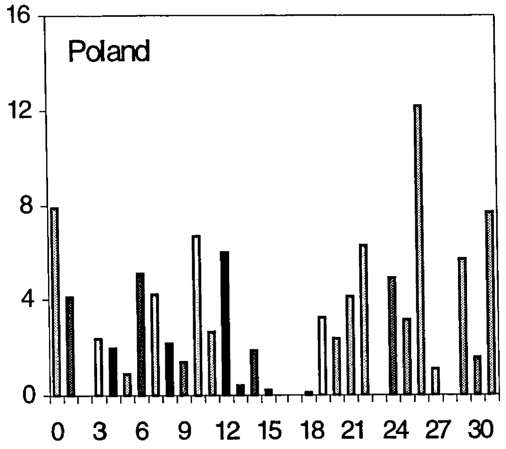
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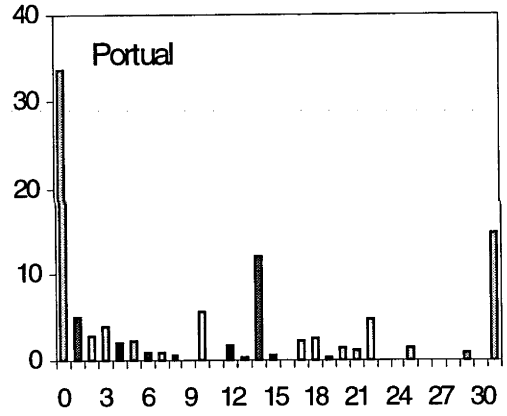
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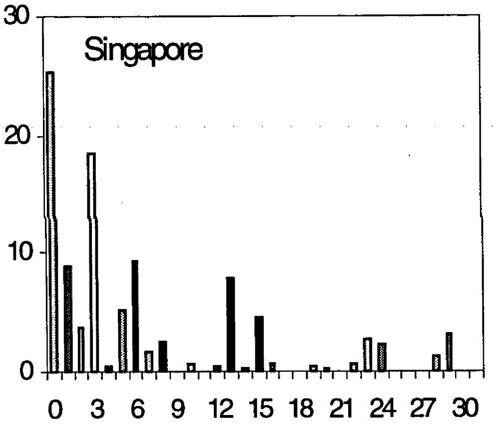
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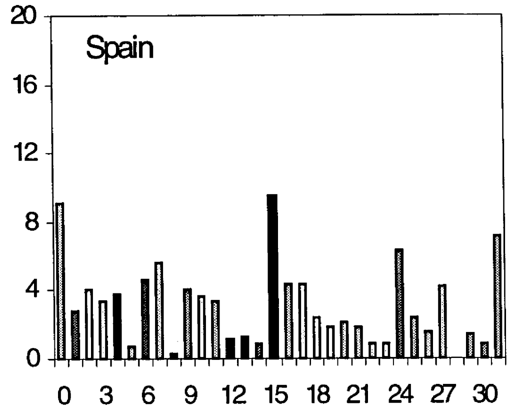
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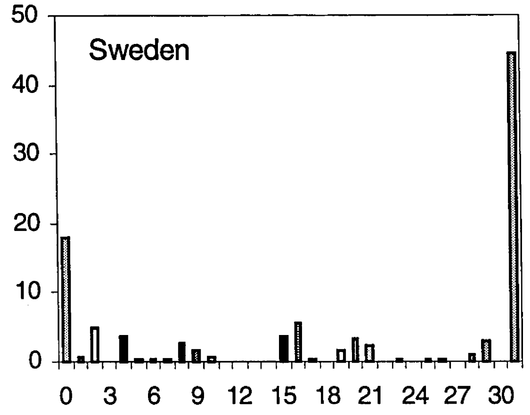
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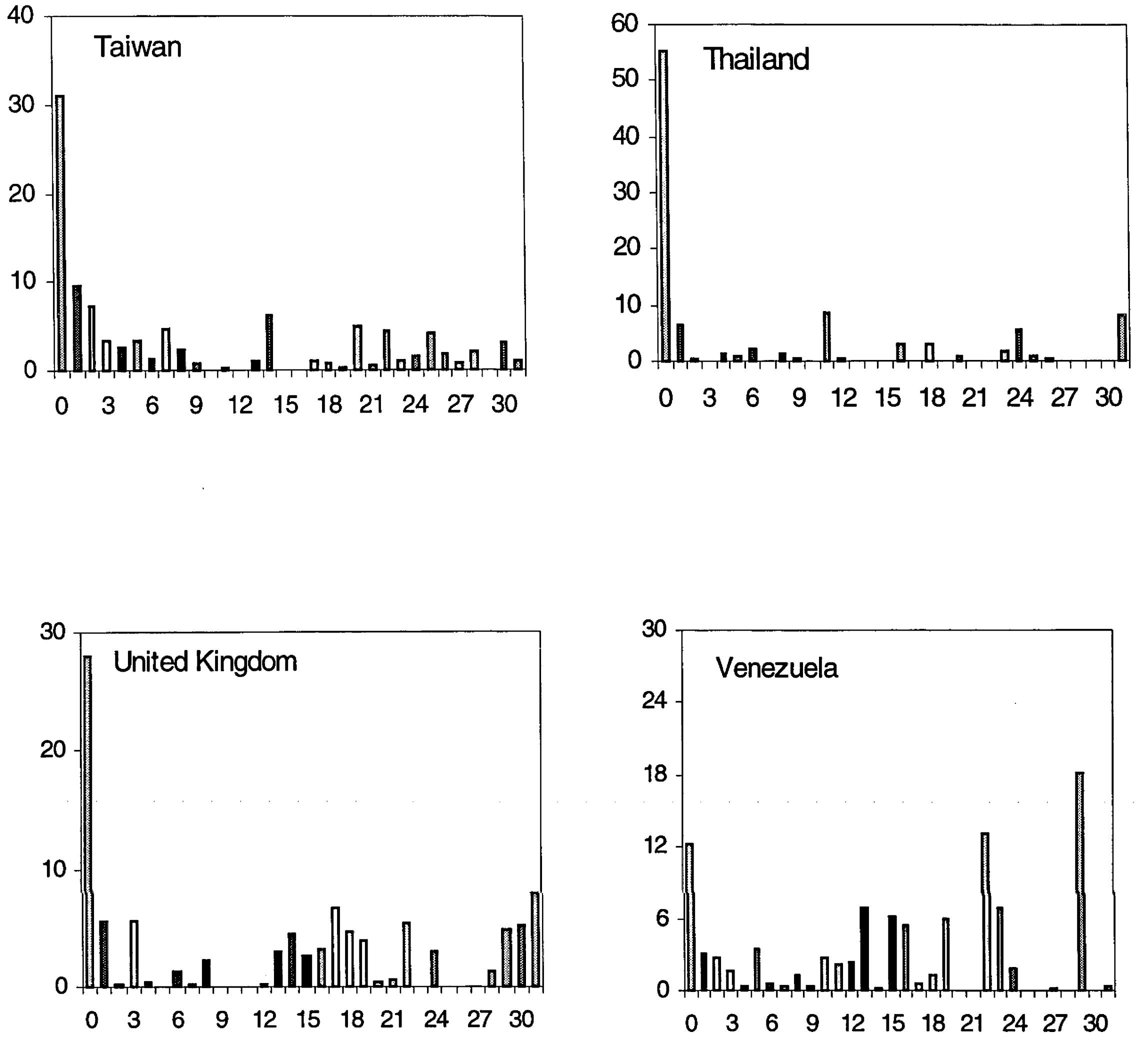

Notes: The horizontal axis denotes number of years in specialisation. The vertical axis denotes percentage trade share in total ESGs.
Source: Author's calculations on the basis of the United Nations COMTRADE database from International Economic Data Bank, Australian National University.

4 Trade in Embodied Environmental Factor Services: A-Factor-Content-of-Trade Approach

The environment as a factor of production

In the literature of trade and environment, the environment[1] is generally conceived of as a byproduct of the production and/or consumption of ESGs, or it is treated as a factor of production. The conventional textbook approach to environmental economics adopts the former approach (Baumol and Oates 1988). In this context, pollution is due to externalities that arise as a result of the production and/or consumption of ESGs. The result of these externalities is to drive a 'wedge' between the private and social marginal cost of production. This 'wedge' can then be corrected through a Pigovian tax-sum-subsidy scheme.

This approach can be extended to analyse the effects of trade liberalisation on production and trade in the environment. A simple partial equilibrium model is often used to illustrate such effects (Anderson and Blackhurst 1992).

However, the idea that the environment should be treated as a factor of production can be traced to Coase's well-known paper (Coase 1960). In his paper, Coase showed that, even if the Pigovian tax is exactly adjusted to equal the damage that would be done to society as a result of the negative production externality, the tax would not necessarily bring about Pareto optimal solutions. This interesting finding leads Coase to insist on a change of approach so that the environment is treated as a factor of

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[1] For example, pollution.

production. 'If factors of production are thought of as rights, it becomes easier to understand that the right to do something which has a harmful effect (such as the creation of smoke, noise, smells, etc.) is also a factor of production' (Coase 1960: 44).

The idea that the environment can be treated as a factor of production has recently been formally incorporated into theoretical modelling (Siebert 1987; Lopez 1992; among others). For example, Siebert (1987) interprets nature and the environment as a scarce resource. Ramon Lopez (1992) extends the conventional neoclassical production function to include the environment. In that model, total industry output is also a function of the environmental factor of production, $y_i = G^i [f^i (K_i, L_{i,;} t), x_i; r]$, where y_i is the output of industry i, x_i is the environmental factor used by industry i and r is an index of technology. Lopez argues that it is necessary to distinguish two types of environmental factor. The first type is that which does not have stock feedback effects in production, such as air pollution. Air quality tends to improve very fast when the rate of air emissions is reduced. In the case of air as an environmental factor, x_i is air emissions produced by industry i. The other type is an environmental resource that has both flow and stock feedback effects on production. Examples of these are forest resources, fish stocks and agricultural soil depth. In these cases, production can expand in the short run by more intensive exploitation of the resource, but at the cost of a gradual reduction in the stock, which eventually may decrease productivity in the respective industries.

It is well known that international trade in goods can be interpreted as indirect flows of factor services. Thus, international trade in ESGs can also be interpreted as indirect flows of environmental factor services if the environment is treated as a factor of production. It would be interesting to investigate the trade patterns of embodied environmental factor services across a range of countries over time. The results could be compared with those obtained in the previous chapter in which attention is focused on the changing pattern of tradable goods that move across borders over time. These are two basic approaches to testing trade theory, particularly the Heckscher–Ohlin (H–O) Theorem.

The concept of trade in embodied environmental factor services, where pollution is the environmental factor, captures the idea that traded goods embody an environmental factor service. It reflects the amount of pollution emitted domestically for goods produced for export. The relevance of this concept in investigating the trade effects of environmental policy lies in the fact that the factor-content-of-trade approach is an alternative to the trade-in-goods approach. A simple example (applying the H–O Theorem) is that if countries have different domestic environmental policies, their ability to pollute or their abundance of environmental services[2] might differ. In the resulting trade pattern, one would expect countries with stringent environmental regulations to have more embodied environmental factor services in their imports than that in their exports, while countries with less stringent environmental regulations might reveal the opposite pattern. However, as discussed below, it becomes very hard to predict the indirect movement of a particular factor when there are more than two factors.

Trade in embodied environmental factor services

Surprisingly, there are few studies in the literature that look at trade in embodied

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[2] We assume the same assimilative capacity, social preference and focus on institutional arrangements.

environmental factor services. In one of the earliest studies, Walter (1973) looks into the pollution content of US trade. The question Walter asks is whether 'environmental-control charges actually incurred by industry form an essentially trade-neutral pattern, or whether they are fundamentally export-biased or import-biased'. Walter calculates direct and overall environmental-control (including those from intermediate goods) charges for 83 goods and services categories contained in the 1966 US input–output table. The environmental-control cost (ECC) is approximated using the estimated direct and indirect costs attributable to environmental management which include current R&D expenditure for compliance, depreciation on current pollution abatement equipment, the capital cost of that equipment, and current operating costs associated with environmental management.

The estimated ECC per dollar of sales, together with the input–output coefficients, is then used to calculate the direct and overall ECC for each of the 83 sectors. The resulting estimates are multiplied by the average annual export (import) value for each sector and the summation across 83 sectors gives the pollution content of US exports (imports). One should note that the same ECC coefficients are used for both exports and imports when ideally foreign trade partners' ECC coefficients should be used for the pollution content of US imports. The pollution content of US exports is found to be 1.75 per cent of total exports while the pollution content of US imports is found to be 1.52 per cent of total imports. Walter interprets this difference to be insignificant, and concludes that ECCs are trade-neutral at best and marginally biased against US export industries at worst.

Another study that investigates trade in embodied environmental factor services is Robison's work (1988). He also looks into the pollution content of US trade for 1973, 1977 and 1982 using input–output tables for 1973 and 1977. This discrete time-series result indicates that the ratio of the abatement content of US imports to US exports has risen from 1.151 in 1973, to 1.167 in 1977 and 1.389 in 1982. On the basis of this result, Robison concludes that 'there is some evidence that US pollution control programs have changed the US comparative advantage such that more high-abatement-cost goods will be imported and more low-abatement-cost goods exported'. This result differs from that of Walter (1973). Walter's study shows that the ratio of abatement content of US imports to US exports in 1968–70 is 0.812,[3] which indicates that the United States exports more environmental factor services than it imports.

Embodied environmental factor services: data and methodology

In this section, the idea of the factor content of trade is introduced and a modified version is derived for the estimation in the next section. The factor content of trade approach was first employed by Leontief (1953) in his well-known test of the Heckscher–Ohlin (H–O) Theorem and later formalised theoretically by Travis (1964), Vanek (1968), Melvin (1968), Deardorff (1982) and many others.

We consider a world in which l primary factors combine to produce m goods in n countries. Factors cannot be traded but goods can. A country's consumption, exports and imports are described by the following vectors: $C^j = (C_1^j, \ldots, C_m^j)$, $X^j = (X_1^j, \ldots, X_m^j)$ and $M^j = (M_1^j, \ldots, M_m^j)$ are m-dimensional vectors of final consumption demands for goods in country j, exports and imports of country j, respectively; and $T^j = (T_1^j, \ldots, T_m^j)$ is an m-dimensional vector of country j's net

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[3] This number is calculated using the average annual overall environmental control loadings of US imports during the 1968–70 period, that is, US\$751 million, divided by that of US exports during the same period, that is, US\$609 million.

exports. Elements of T^j will be negative for goods which are net imports. A country's net export vector can then be written in the following form:

$$T \equiv X - M \tag{4.1}$$

We then define V^X, V^M, V^T and V^C as the actual quantities of factors embodied in ***X***, ***M***, ***T*** and ***C***, respectively. Constant returns to scale and no joint production are assumed so that techniques of production can be represented by the amount of inputs used per unit of output of each good. Various production techniques can therefore be represented by the input–output coefficient matrices $A(w)$, where a_{hi} denotes the direct-plus-indirect requirement of factor *h* per unit of output of good *i*.

The factors embodied in ***X*** are equal to

$$V^X = A(w)X \tag{4.2}$$

and the factors embodied in ***M*** are

$$V^M = A^*(w^*)\,M \tag{4.3}$$

where a foreign country's input–output coefficient matrices are distinguished by asterisks. Note that if the countries have homogenous, identical technology and factor prices are equalised, we obtain

$$A(w) = A^*(w^*).$$

According to Deardorff (1982), the three versions of the factor content of trade can be defined as follows.

1. Factor content based on domestic coefficients, V^{TD}. This factor content of trade definition imputes factors to goods on the basis of domestic techniques of production, i.e. $A(w)$. This gives

$$V^{TD} = A(w)X\text{-}A(w)M = A(w)T \tag{4.4}$$

2. Actual factor content of trade, V^{T}: This imputes to traded goods those factors actually used in their production wherever that took place. This gives

$$V^{T} = V^{X}\text{-}V^{M} = A(w)X\text{-}A^{*}(w^{*})\,M \tag{4.5}$$

3. Factor content based on actual content of consumption, V^{TC}. This refers to the difference between country *j*'s endowment of factors and the factors that are embodied in its consumption. In other words,

$$V^{TC} = V\text{-}V^{C} \tag{4.6}$$

where V is the total factor endowment vector of country *j*.

If the countries have homogeneous, identical technologies and factor prices are equalised, we obtain $A(w) = A^{*}(w^{*})$. So definition 1 is equivalent to definition 2. If full employment is further assumed, the three definitions of the factor content of trade are identical.

If pollution is treated as one type of environmental factor service, the pollution intensity can be measured using the input–output coefficients, $A(w)$, for each sector. Then, the factor content of trade for each country can be calculated using equation (4.5)

$$V^T = V^X - V^M = A(w)X - A^*(w^*)\,M \qquad (4.5)$$

Since detailed sectoral pollution intensity data for trading partners (except the United States) are generally not available, I follow Walter (1973) and Robison (1988) by assuming that US pollution intensity can be applied to other countries. This is not a harmless assumption, however, because it could lead to an underestimation of the pollution content of exports for countries with lower environmental regulations than the United States, and an overestimation of pollution content of exports for countries with higher environmental regulations than the United States. In the case of imports, this can also lead to an underestimation of the pollution content of imports for countries with higher environmental regulations relative to their trading partners. This point must be borne in mind when providing interpretations of the pollution content of trade for a particular country.

Equation (4.5) becomes

$$V^T = V^X - V^M = A(w)^{\mathrm{US}}X - A(w)^{\mathrm{US}}\,M \qquad (4.7)$$

where $A(w)^{\mathrm{US}}$ denotes the pollution intensity matrix in the United States.

Two problems arise when one tries to apply real world data to equation (4.7).[4] First, changing values of exports and imports for a country may simply be due to export or import price changes without any real changes. The use of value rather than volume of exports and imports may, therefore, bias the result[5] as was the case in Walter (1973). Second, a macroeconomic imbalance, such as a persistent national saving and investment imbalance, may lead to substantial changes in net exports without any structural implications.[6] For example, the United States experienced persistent current account deficits, with current account deficits as a percentage of GDP at 3.70 in 1987 and an annual average of 2.0 in the 1980s.[7] It is obvious that these effects need to be removed if meaningful results are to be derived.

We therefore propose to modify equation (4.7) as follows.

$$V_{jt}^{T} = \sum_{i}\left(\frac{a_i^{US} X_{ijt}}{\sum_{i} X_{ijt}}\right) - \sum_{i}\left(\frac{a_i^{US} M_{ijt}}{\sum_{i} M_{ijt}}\right) \tag{4.8}$$

where i is sector i.

j is country j.

t is year t.

a_i^{US} is pollution intensity index measured by the LAHTI[8] index for the United States.

X_{ijt} is sector i's exports for country j in year t.

M_{ijt} is sector i's imports for country j in year t.

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[4] Both Walter (1973) and Robison (1988) make use of this equation in their studies.

[5] See further discussion in the section on structural changes.

[6] For example, factor endowment changes.

[7] This is calculated on the basis of data from World Development Indicator 1997, World Bank and International Economic Databank, the Australian National University.

[8] The definition follows below.

V_{jt}^{T} is factor content of trade for country *j* in year *t*.

This modification takes into consideration the above two problems. Instead of using the export value for country *j* in year *t*, the export share of sector *i* for country *j* in year *t* is used. This abstracts away the inflation effect if it is an across-the-board increase in the prices of all commodities. The assumption of a uniform across-the-board price increase is equivalent to deflating the export value by the export unit value index, an approach commonly adopted in applied trade analysis. As will be argued later in this chapter, this modification also removes the effects of macroeconomic imbalances such as current account deficits. A 1 per cent increase in exports spread uniformly across all goods (for example, when domestic savings are greater than domestic investment) will not affect the level of this share. This method distinguishes this study from those of Walter (1973) and Robison (1988). The significance of this modification will be discussed further later.

In order to capture the changing patterns of the pollution content of trade for each country in the last 26 years, a normalisation is carried out so that the pollution content of net exports for each country in 1970 is normalised to unity. Depending on the initial condition, this normalisation can yield a positive or negative unity. If positive, this indicates that this country's exports are more pollution-intensive than its imports. The reverse holds for a negative unity. From a time-series perspective, starting from a positive result in year 1970, a number greater than one, say 1.3, in the later years, $t = 1970 + n$ with $n = 1, \ldots, 26$, indicates that the pollution content of exports for country *j* in year *t* is 1.3 times as great as that in 1970. A change of sign indicates a structural change in the pollution content of trade.

To explore further whether there are structural changes on the patterns of embodied environmental factor services trade, the import content of embodied environmental factor services trade, as measured by

$$V_{jt}^{M}=\sum_{i}\left(\frac{a_{i}^{US}M_{ijt}}{\sum_{i}M_{ijt}}\right) \tag{4.9}$$

is then divided by the export content of embodied environmental factor services trade, as measured by

$$V_{jt}^{X}=\sum_{i}\left(\frac{a_{i}^{US}X_{ijt}}{\sum_{i}X_{ijt}}\right) \tag{4.10}$$

That is,

$$I_{jt}=\frac{V_{jt}^{M}}{V_{jt}^{X}} \tag{4.11}$$

An index of greater than unity, $I_{jt} \succ 1$, indicates that country *j*'s imports are more pollution-intensive than its exports in year *t* while an index of less than unity indicates that country *j*'s exports are inherently more pollution-intensive than its imports in year *t*.

In terms of data, this study differs from those of Walter (1973) and Robison (1988) in that I use a newly available index, the Linear Acute Human Toxic Intensity (LAHTI) index,[9] developed by the Industrial Pollution Projection System (IPPS) of the World Bank in 1994,[10] to measure the embodied environmental factor services. The LAHTI index belongs to the family of pollution intensity indexes and it measures the amount of pounds of toxic chemical releases and transfers per US$1,000.

The highest LAHTI index is for fertilisers and pesticides (ISIC 3512) with 105.3 risk-weighted pounds of toxic chemical releases and transfers per US$1,000 of product shipped while the lowest LAHTI index is for soft drinks and carbonated water (ISIC 3134), with only 0.22 pounds per US$1,000. The LAHTI index generally confirms the intuitive belief that the most intensive sectors in terms of toxic waste per dollar of output are industrial chemicals, plastics, paper and metals. The middle-ranked sectors are associated with consumer products such as electrical appliances, textiles, and cleaning preparations, followed by the high shipment value (and consequently relatively low intensity) machine-tool industry, with the food and drink sectors filling the least intensive rankings. This pattern of pollution intensity also largely conforms to the ESGs that are used in the previous chapter.

Data for exports and imports by ISIC sector for each country from 1970–96 are calculated. This is done by making a concordance between ISIC and SITC codes.[11] I have data for 29 countries' exports and imports for each ISIC four-digit sector in the last 26 years. These ISIC four-digit sectors match the sectors of the pollution intensity developed by World Bank IPPS project (1994).

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[9] Lee and Roland-Holst (1997) also use this index for a different sort of examination of the pollution content of Japan and India's trade.

[10] For a detailed discussion of the construction of this index, see Hettige, Marin, Sinh and Wheeler (1994).

[11] This work was carried out at International Economic Databank of the Australian National University.

Some caveats are in order. Deardorff (1982), Ethier (1984) and Helpman (1984) provide the factor-content version of the general law of comparative advantage as summarised in Wong (1995). With identical technologies across countries, a country *on average* indirectly exports the factor that is cheaper under autarky. However, it becomes very hard to predict the indirect movement of a particular factor when there are more than two factors.

Since the focus of this study is whether there are systematic structural changes in the pattern of the embodied environmental factor service trade, the problem of predicting indirect movements of environmental factor services is not of great interest here. If stringent environmental factors do have significant impacts on the export performance of ESGs, one would expect a significant fall in net exports of embodied environmental factor services exports and a significant increase of embodied environmental factor services imports. It is this hypothesis that I investigated using a trade-in-goods approach in the previous chapter. The next section examines this using a factor-content-of-trade approach.

Are there structural changes?

Table 4.1 presents trends in net exports of environmental factor services, with a normalisation performed in 1970. Two distinct features emerge from this table. First, I turn to changes in sign that indicate significant structural changes of the pollution content of trade. I observe that the sign remains unchanged in this period for the majority of countries. Countries that are net importers of environmental factor services remained so throughout the period examined, as did countries who were net exporters of environmental factor services. Take the United States as an example. If net exports of environmental factor services are normalised to unity for 1970, this index remains around unity in the 1970s. If the introduction of stringent environmental regulation has significant effects on trade patterns, we would expect a significant decline of net exports of environmental factor services. However, this is not what I observe. There are even slight increases in net exports of environmental factor services in the 1980s, and this index declines to 1.3 in 1996. This indicates that no systematic structural changes occurred in patterns of the pollution content of trade despite the introduction of higher environmental regulations in the 1970s and 1980s in most developed countries. This result is generally consistent with what I found using the trade-in-goods approach in the previous chapter. Of course, there are a few exceptions, for example, Australia, Ireland and Malaysia. A simple correlation test indicates there is a positive correlation between the performance in the initial year and that of the end year (see Figure 4.1).

Second, I examine the variations for each country across time. Table 4.1 also calculates the mean and variance of each country in the period 1970–96. The variance is low except for Japan, the United Kingdom, Malaysia, Australia, Taiwan and Mexico.

When I plot net export performance of environmental factor services in 1971–75 against that in 1991–95 for each country selected, I obtain the picture shown in Figure 4.1. The underlying data are given in column 3 and 7, Table 4.1. As this figure reveals, most of the data points are bunched in the first (northeast) and the third (southwest) quadrants, suggesting very strongly that there is a positive correlation between the net export performance of environmental factor services in 1971–75 and that in 1991–95. This indicates that countries that are net importers of environmental factor services remained so throughout the period examined, as did countries who were net exporters of environmental factor services.

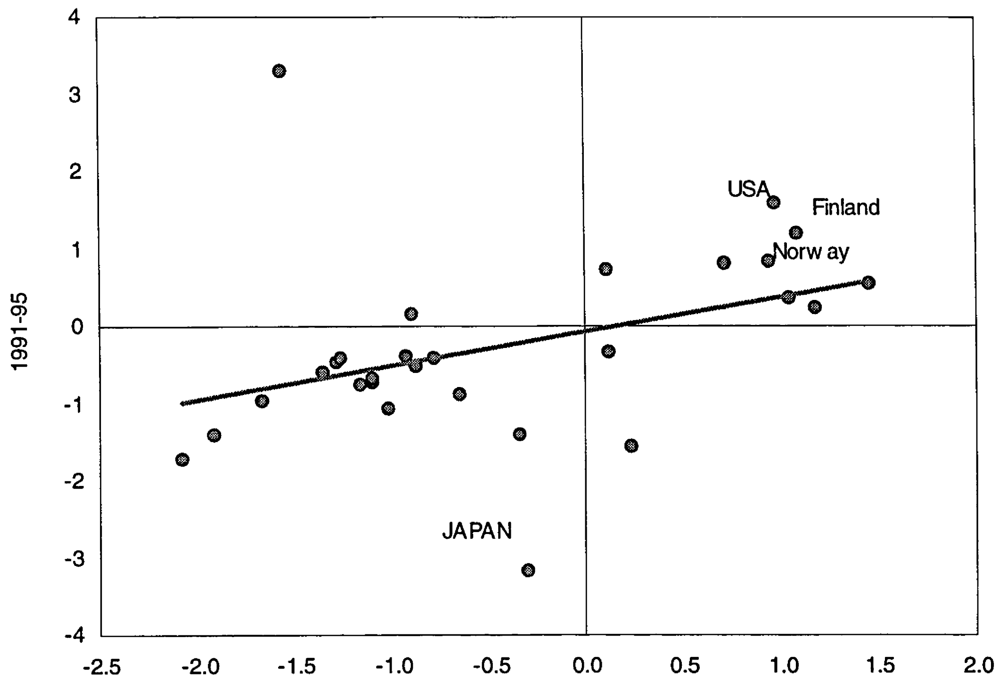
Table 4.1 Indices of net exports of environmental factor services: 1970 = 1

	1970	1971–75	1976–80	1981–85	1986–90	1991–95	1996	Mean	Variance
US	1.0	1.0	1.0	1.7	2.6	1.6	1.3	1.5	2.0
Japan	-1.0	-0.3	-2.7	-5.5	-4.8	-3.2	-1.6	-2.7	22.7
Germany, Fed.	1.0	1.4	0.6	0.0	-0.1	n.a.	n.a.	0.6	
France	-1.0	-1.2	-1.2	-1.0	-0.7	-0.7	-0.9	-0.9	0.3
United Kingdom	-1.0	0.1	0.9	2.0	2.1	0.7	-0.4	0.6	7.9
Italy	-1.0	-0.6	-1.0	-0.6	-0.8	-0.9	-0.6	-0.8	0.2
Finland	1.0	1.1	0.3	0.6	1.8	1.2	1.5	1.1	1.5
Norway	1.0	0.9	1.0	1.4	1.4	0.8	0.5	1.0	0.6
Sweden	-1.0	-1.1	-1.3	-1.5	-0.4	-0.7	-0.8	-1.0	0.8
Denmark	-1.0	-1.1	-0.9	-1.0	-0.8	-0.7	-0.5	-0.9	0.3
Netherlands	1.0	1.5	1.5	1.5	1.4	0.5	0.6	1.1	1.1
Ireland	-1.0	-0.9	-0.5	-0.2	-0.3	0.2	0.5	-0.3	1.7
Spain	-1.0	-0.9	-0.9	-0.6	-0.3	-0.5	-0.6	-0.7	0.3
Belgium-Luxemburg	1.0	1.2	1.0	0.5	0.2	0.2	0.1	0.6	1.2
Canada	1.0	1.0	1.2	0.8	0.7	0.4	0.1	0.8	0.9
Australia	-1.0	-1.6	5.0	8.1	2.5	3.3	4.8	3.0	70.9
New Zealand	-1.0	-0.9	-0.9	-0.8	-0.5	-0.4	-0.3	-0.7	0.4
Greece	1.0	0.1	-0.1	-0.6	-0.6	-0.3	0.0	-0.1	1.7
Singapore	-1.0	-2.1	-1.9	-1.4	-1.4	-1.7	-1.7	-1.6	0.8
Korea	-1.0	-1.4	-1.1	-1.1	-1.1	-0.6	-0.4	-1.0	0.6
Hong Kong	-1.0	-1.0	-1.1	-1.0	-1.2	-1.1	-1.0	-1.0	0.0
Taiwan	-1.0	-1.7	-1.7	-1.6	-1.5	-1.0	-0.9	-1.3	0.8
Mexico	1.0	-0.3	-0.3	-0.5	-1.2	-1.4	-2.4	-0.7	6.9
Chile	1.0	0.7	1.6	0.8	0.3	0.8	0.9	0.9	0.9
India	-1.0	-1.9	-1.2	-1.4	-1.1	-1.4	-0.4	-1.2	1.3
Indonesia	-1.0	-1.3	-0.3	-0.4	-0.6	-0.5	-0.5	-0.7	0.7
Malaysia	1.0	0.2	-1.4	-1.5	-1.9	-1.6	-1.2	-0.9	7.1
Philippines	-1.0	-1.3	-0.9	-0.9	-0.5	-0.4	-0.4	-0.8	0.7
China	-1.0	-0.8	-0.6	-0.5	-0.4	-0.4	-0.4	-0.6	0.3

Note: ‘n.a.’ denotes ‘not available’.

Source: Author’s calculations on the basis of UNIDO and UN COMTRADE database at International Economic Databank, the Australian National University.

Figure 4.1 Net exports of environmental factor services: 1970–75 vs 1991–95



Note: The horizontal axis denotes values in 1971–75; the vrtical axis denotes 1991–95 values.
Source: Author's calculations.

Similar patterns can be found in Table 4.2 where the pollution content of imports to exports ratios is calculated. For example, the United States has a pollution content of imports to exports ratio of 0.90 in 1970–72, indicating that the United States exported more environmental factor services than it imported. This ratio remains relatively unchanged and is 0.82 in 1994–96. Western European countries, such as Finland, Norway, Netherlands and Belgium-Luxembourg, also export more environmental factor services than they import, again without experiencing any structural changes, despite the fact that stringent environmental regulations were introduced in the 1970s and 1980s.

Strikingly, most of the developing countries import more environmental factor services than they export. Newly industralising economies (NIEs) such as Korea, Taiwan, Singapore, Hong Kong and Mexico, import more pollution-intensive goods than they export, with a persistent pattern since the 1970s when the data are first available. Developing East Asian countries such as China, India, Malaysia, the Philippines and India also import more environmental factor services than they export, with countries like China, the Philippines and Indonesia exhibiting a slightly declining trend.

The time-series patterns of the environmental factor content of trade observed differ significantly from the predictions of conventional wisdom. Developed countries overall export more environmental factor services than they import while developing countries import more environmental factor services than they export, despite the fact that stringent environmental standards have been in place since the 1970s in developed countries. This finding therefore merits further explanation. Relatively stringent environmental regulation in developed countries implies relatively scarcity in environmental factor endowment. However, if we allow for technological differences across countries, relative factor abundance has to be reinterpreted in terms of 'effective' factor endowments, as discussed in Chapter 2. With developed countries developing advanced technology in the production of ESGs, the 'effective' factor endowments in developed countries may be more abundant than in developing countries so that developed countries export more environmental factor services. The linkage between environmental regulation and technology innovation will be explored further in a dynamic intertemporal general equilibrium model in Chapter 5. In the meantime, we can accept the fact of technology difference across countries in a static world.

Also, with more than two factors embodied in trade flows, it is very difficult to predict indirect flows of factor services. If environmental regulations do have a significant impact on the international competitiveness of ESG industries, structural changes in the patterns of indirect flows of factor services should be expected. The above results indicate that there are no significant structural changes in the patterns of the environmental factor content of trade.

Table 4.2 Patterns of environmental factor content of trade: import–export ratio (three-year average)

	1970–72	1973–75	1976–78	1979–81	1982–84	1985–87	1988–90	1991–93	1994–96
U.S.	0.90	0.89	0.94	0.86	0.83	0.73	0.75	0.83	0.82
Japan	1.07	1.01	1.25	1.45	1.75	1.83	1.61	1.52	1.30
Germany, Fed.	0.96	0.95	0.98	0.98	1.00	1.01	1.00	n.a.	n.a.
France	1.22	1.19	1.20	1.23	1.16	1.13	1.10	1.12	1.17
United Kingdom	1.05	0.97	0.95	0.92	0.87	0.85	0.87	0.92	1.00
Italy	1.23	1.12	1.22	1.23	1.14	1.16	1.23	1.23	1.22
Finland	0.91	0.93	0.98	0.97	0.95	0.90	0.85	0.90	0.91
Norway	0.73	0.73	0.73	0.69	0.64	0.60	0.65	0.68	0.86
Sweden	1.11	1.09	1.10	1.13	1.15	1.08	1.02	1.06	1.09
Denmark	1.73	1.78	1.58	1.65	1.59	1.45	1.52	1.46	1.33
Netherland	0.84	0.80	0.82	0.80	0.82	0.79	0.85	0.92	0.92
Ireland	2.06	1.70	1.47	1.17	1.09	1.19	1.12	0.96	0.83
Spain	1.44	1.32	1.34	1.30	1.22	1.20	1.08	1.20	1.31
Belgium-Luxemburg	0.83	0.81	0.83	0.85	0.93	0.95	0.96	0.97	0.95
Canada	0.77	0.77	0.76	0.72	0.85	0.84	0.84	0.90	0.94
Australia	1.13	1.06	0.77	0.78	0.69	0.69	1.03	0.92	0.78
New Zealand	3.70	2.99	2.51	2.37	2.33	1.81	1.62	1.63	1.33
Greece	0.79	1.04	1.03	1.08	1.32	1.34	1.21	1.13	1.14
Singapore	1.02	1.17	1.06	1.12	1.06	1.07	1.09	1.09	1.13
Korea	1.52	1.83	1.62	1.38	1.48	1.57	1.56	1.30	1.24
Hong Kong	1.43	1.44	1.48	1.43	1.40	1.58	1.58	1.50	1.50
Taiwan	1.71	2.08	2.00	1.82	1.90	1.87	1.73	1.53	1.48
Mexico	0.97	1.06	1.09	0.93	1.05	1.33	1.05	1.15	1.44
Chile	0.74	0.95	0.67	0.70	0.83	1.06	0.84	0.84	0.78
India	1.66	2.69	1.73	2.00	1.93	1.92	1.78	1.98	1.57
Indonesia	2.10	1.80	1.15	1.25	1.14	1.27	1.28	1.20	1.24
Malaysia	0.86	1.04	1.21	1.31	1.35	1.43	1.44	1.43	1.36
Philippines	2.87	3.73	2.27	1.95	2.06	1.48	1.30	1.39	1.49
China	2.39	2.05	2.02	1.68	1.84	1.35	1.74	1.71	1.49

Source: Author's calculations on the basis of UNIDO and UN COMTRADE database at International Economic Databank, the Australian National University.

A comparision of approaches

In this section, I discuss the significance of my modification of the methodology comparing it with Walter (1973), using data for the United States as an example. Recall that I make use of equation (4.8) in the calculation of the environmental factor content of trade. One interpretation of this approach is that the United States' environmental factor content of trade is simply the trade-share-weighted average of pollution content across ISIC four-digit sectors. Equation (4.8) is written again for convenience as follows:

$$V_{jt}^{T} = \sum_{i}\left(\frac{a_{i}^{US} X_{ijt}}{\sum_{i} X_{ijt}}\right) - \sum_{i}\left(\frac{a_{i}^{US} M_{ijt}}{\sum_{i} M_{ijt}}\right) \tag{4.8}$$

If the United States was shifting away from pollution-intensive goods exports to non-pollution-intensive goods exports, the export-share-weighted average of the pollution content would decrease. This formula can therefore be used to look at the changing trade pattern of embodied environmental factor services.

Walter (1973) makes use of the following approach

$$V_{jt}^{T} = \sum_{i} a_{i}^{US} X_{ijt} - \sum_{i} a_{i}^{US} M_{ijt} \tag{4.12}$$

This is nothing but an explicit expression of equation (4.5). Instead of using trade share as the weight, Walter (1973) uses trade (exports or imports) value as the weight in equation (4.12).

If the assumptions that trade is balanced at all points of time, and that there is no inflation hold, (as in the H–O–V Theorem), there is no problem with using this approach. However, changes in export unit value and/or import unit value and, in particular, changes in macroeconomic balance, would have different implications for trade in environmental factor services. Suppose national saving is less than investment and this transmits directly to a simultaneous increase in the current account deficit. For simplicity, this current account deficit leads to a ε across-the-board increase in imports while exports remained unchanged. This produces a net export content of environmental factor services at time $t + 1$ as follows

$$V_{j,t+1}^{T} = \sum_{i} a_i^{US} X_{ij,t+1} - (1+\varepsilon)\sum_{i} a_i^{US} M_{ij,t+1} \qquad (4.13)$$

This will lead to an exaggeration of the environmental factor content of net exports although there is no significant change in environmental regulation policy. If one makes use of equation (4.8), a ε per cent across-the-board increase in imports with exports remaining unchanged resulting from a macroeconomic imbalance will not lead to any change in the environmental factor content of net exports. To express this more clearly, we have

$$V_{jt}^{T} = \sum_{i}\left(\frac{a_i^{US} X_{ijt}}{\sum_{i} X_{ijt}}\right) - \sum_{i}\left(\frac{a_i^{US}(1+\varepsilon) M_{ijt}}{\sum_{i}(1+\varepsilon) M_{ijt}}\right) = \sum_{i}\left(\frac{a_i^{US} X_{ijt}}{\sum_{i} X_{ijt}}\right) - \sum_{i}\left(\frac{a_i^{US} M_{ijt}}{\sum_{i} M_{ijt}}\right) \qquad (4.14)$$

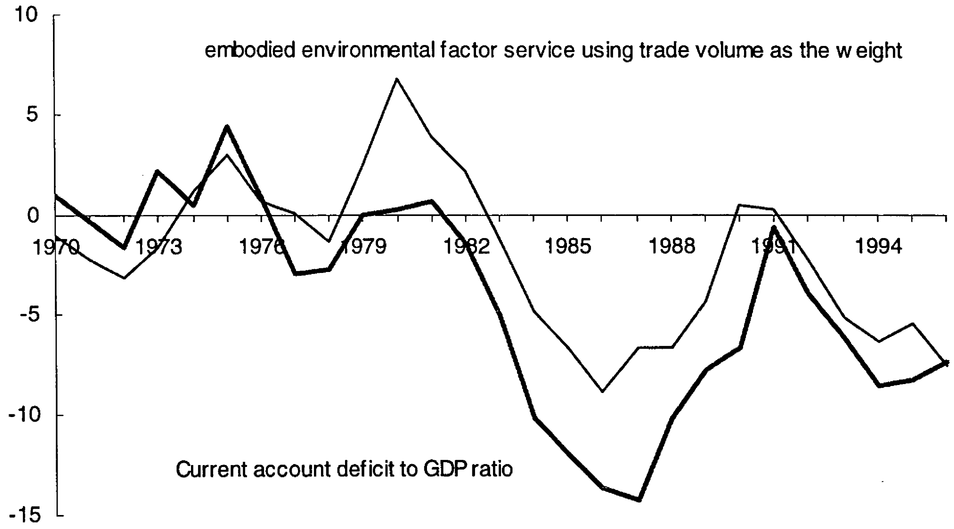
So V_{jt} remains unchanged.

Using the United States as an example, I first deflate US export and import values by the export unit value and import unit value indexes to remove any inflationary effects. Then I make use of equation (4.12) to calculate the environmental content of trade from 1970 to 1996. The resulting volume of environmental factor services is then normalised to unity in 1970. In order to see how macroeconomic imbalance affects the result, I also normalise the United States' current account deficit as a percentage of GDP so that it is also one in 1970.

Figure 4.2 presents the changing pattern of these two indicators. The most striking feature is that the changing pattern of trade in embodied environmental factor services closely follows the current account imbalance. This is not surprising given the fact that, as reflected in equation (4.13), a change in the macroeconomic balance will lead to an exaggeration of the environmental factor content of net exports. Unless the effects of macroeconomic imbalance in the United States in the 1970s and 1980s are taken into account, the resulting trend in the pattern of environmental factor services can be very misleading.

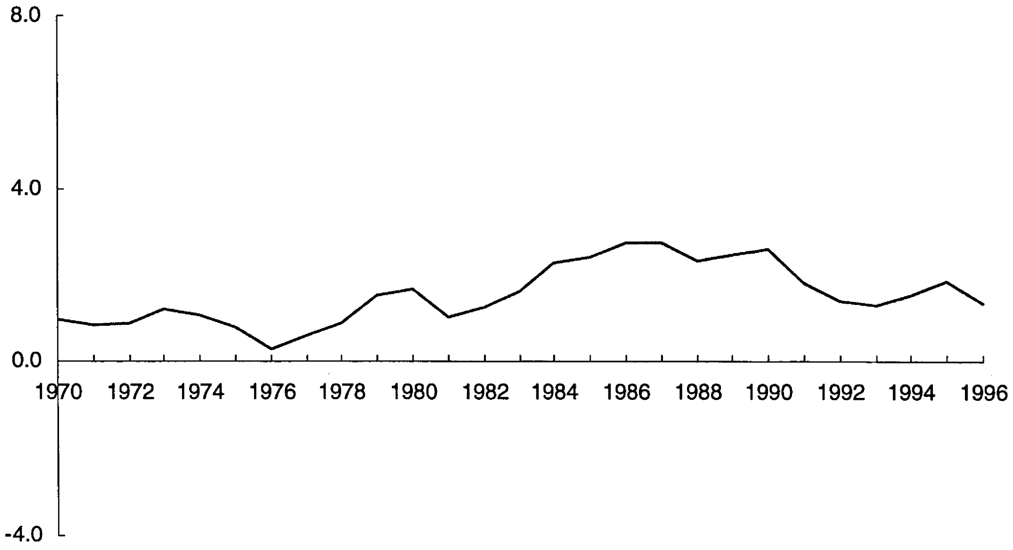
This can be demonstrated using equation (4.8). A macroeconomic imbalance will not lead to any changes in the environmental factor content of net exports if one applies equation (4.8). (See equation (4.14) for details.) Figure 4.3 plots the changing pattern of environmental factor services from 1970 to 1996 after removing the inflationary effect and the macroeconomic imbalance effect. I can now compare it with what I observe using export (import) value as the weight. The significant difference is that there actually was a persistent trade pattern of embodied environmental factor services in the last 26 years in the United States.

Figure 4.2 United States: current account imbalance and trends of embodied environmental factor services trade using trade volume as the weight



Source: Author's calculations. Data for exports and imports are from UNIDO. Data for export and import unit value, current account as a percentage of GDP are from International Financial Statistics, International Monetary Fund.

Figure 4.3 United States: trends of embodied environmental factor services trade using trade share as the weight



Source: Author's calculations. Data for exports and imports are from UNIDO. Data for export and import unit value, current account as a percentage of GDP are from International Financial Statistics, International Monetary Fund.

Conclusion

In this chapter, the environment has been treated as a factor of production. On the basis of this perspective, this chapter investigates the changing patterns of trade in embodied environmental factor services across more than 70 ISIC sectors for 29 countries in the period 1970–96.

There are few studies of the environmental factor content of trade in the literature. This study differs from those of Walter (1973) and Robison (1988) in terms of both data and methodology. A newly available dataset for a pollution intensity index constructed by the IPPS project of the World Bank in 1994 is used in this study. Instead of using trade value to calculate net exports of environmental factor services, I use the trade-share-weighted average to impute the net export content of environmental factor services. The significance of this modification is that it removes biases from both the effects of inflation and macroeconomic imbalance. The result indicates that the net export content of environmental factor services for the majority of the countries in the study does not experience systematic structural change in the last 26 years, despite the introduction of stringent environmental regulations in most of the developed countries in the 1970s and 1980s. This observation is generally consistent with the observations in the last chapter using a trade-in-goods approach.

5 Trade Effects of Domestic Environmental Policy: A Multi-Country Econometric Analysis

We have made use of both the trade-in-goods approach (in Chapter 3) and the trade-in-factor-services approach (in Chapter 4) to explore time-series evidence on the trade effects of environmental policy across countries. The striking and robust feature revealed in these two chapters is that the export performance of ESGs for most of the countries does not reveal systematic changes in the last three decades, despite the introduction of stringent environmental regulations since the 1970s. In this chapter, this phenomenon is subjected to a multi-country econometric test using an extended gravity-equation framework. In this framework, bilateral exports depend on the countries' size and wealth, degree of inward orientation, geographic distance that measures the natural obstacles to trade between trading partners and 'artificial' obstacles such as tariffs and environmental stringency. The extent of environmental stringency is measured by unique indices recently developed by the World Bank.

I test the following two hypotheses. The first hypothesis is that more stringent environmental regulations lower total exports, and/or exports of ESGs, and/or exports of non-resource-based ESGs. The second hypothesis is that new trade barriers emerge to offset the effects of more stringent environmental regulations.

My findings reject the above two hypotheses. Overall, more stringent environmental regulations do not reduce total exports, exports of ESGs or exports of non-resource-based ESGs. Neither was there any evidence to support the hypothesis that new trade barriers emerge to offset the effects of more stringent environmental regulations.

Furthermore, higher import tariffs in trading partners are found to reduce significantly a reporter country's export performance in total exports, ESGs and non-resource-based ESGs exports. These results conform to the empirical time-series observations in Chapters 3 and 4 and may reflect the extent to which increases in the stringency of environmental regulations are accompanied by technological innovation so that the export performance of ESGs does not deteriorate.

The rest of this chapter is organised as follows. It first develops the two main hypotheses that are testable in the gravity-equation framework. It then describes the extended gravity equation with environmental stringency and import tariffs variables and presents the data and the measurement used in the study, followed by a discussion of the empirical results. The last section provides some conclusions.

The hypothesis

The effect of domestic environmental policy on trade flows has been a major concern both to governments and private sectors in many countries. Introducing a higher environmental standard into the economy imposes additional costs to the production of ESGs and may, therefore, exert a negative impact on the export performance of ESGs. As a result, concerns have been expressed that countries with higher environmental regulations may lose their comparative advantage in the production and exports of ESGs.

The empirical literature on testing the trade effects of domestic environmental policy has mainly followed the conventional Heckscher–Ohlin approach, with net exports of disaggregated industries as the explanatory variable in a multilateral trade flow context (for example, Kalt 1988; Tobey 1990). Van Beers and van den Bergh (1997), however, argue that a disadvantage of this approach is that the effects of differences in strict environmental regulations on trade flows between countries may cancel out as multilateral trade flows are an aggregate of bilateral trade. Furthermore, changes in the stringency of environmental regulations may have different impacts on resource-based and non-resource-based (footloose) environmentally sensitive industries. Non-resource-based ESGs can respond to changes of environmental costs by migrating to countries with less stringent environmental regulations (Markusen *et al.* 1993). On the other hand, resource-based ESGs may not be sensitive to alterations in the stringency of environmental regulations. Jaffe *et al.* (1995), for example, argue that natural resource endowments may partly or largely explain the pattern of pollution-intensive exports. Therefore, testing the effects on exports of non-resource-based environmentally sensitive goods may be a more sensible approach than testing total exports or total ESGs.

It is well known that importing countries' trade tariffs exert negative effects on their trading partners' export performance. It has also been argued that trade barriers may emerge to offset the trade effects of more stringent environmental regulations. For example, Leidy and Hoekman (1994) discuss the possibility that new trade barriers may have emerged to offset the effects of more stringent environmental regulations. It is, therefore, necessary to disentangle the trade effects that arise from reporter countries' relatively stringent environmental regulations from their own and their trading partners' high import tariffs. I shall include indicators that measure the degree of trade protection and test these effects explicitly.

I therefore set out the hypothesis of this study as follows.

Hypothesis I Higher stringency of environmental regulations lowers total bilateral exports, bilateral exports of ESGs and bilateral exports of non-resource-based ESGs.

Hypothesis II New trade barriers emerge to offset the trade effects of more stringent environmental regulations.

Although Van Beers and van den Bergh (1997) employ a similar framework to test the trade effects of environmental policy, this study differs from theirs in three major ways. First, I use a recently available, unique environmental performance index developed by a World Bank research team after two years' work based on 31 countries' environmental reports presented to the United Nations Conference on Environment and Development (UNCED) in 1992 by 145 countries. The UNCED reports are similar in form as well as coverage, and permit cross-country comparisons. This is expected to minimise significantly any possible measurement errors arising from inter-country environmental regulations.

Secondly, my sample avoids possible sample selection bias, which is a crucial issue in drawing inferences from the sample regression results. 'The 31 UNCED report countries were selected randomly from the total of 145 by the Work Bank research team. These 31 countries range from highly industrialized to extremely poor, they are drawn from every world region, and they range in size and diversity from China to Jamaica' (Dasgupta *et al.* 1995: 3). Van Beers and van den Bergh's (1997) sample consists of 21 OECD countries only. Since the trade effects of domestic environmental policy are mainly a North–South rather than a North–North problem, there is an obvious sample selection bias problem in their study.

Thirdly, a technical deficiency relating to their measurement of export flows is that macro fluctuation is not properly taken into account. They pick up exports in a particular year (1992) without removing the effects of cyclical and macro disturbances. This might bias the results significantly, as discussed in Chapter 4.

Empirical model of trade with environmental regulations

In the 1960s the gravity model was developed independently, by Dutch economists Tinbergen (1962) and his collaborator Linnemann (1966) and Finnish economists Pöyhönen (1963) and Pulliainen (1963). It has been used extensively in empirical studies of international trade since then. As Anderson put it, the gravity equation is '[p]robably the most successful empirical trade device of the last twenty-five years' and 'usually produces a good fit' (1979: 106). The theoretical foundations of the gravity model can be found in Anderson (1979), Helpman and Krugman (1985), Helpman (1987) and Bergstrand (1985; 1989; 1990). According to this static general equilibrium model, bilateral trade is determined by three factors, as discussed extensively by Linnemann (1966): (1) factors indicating total potential supply of exporting countries, such as exporting countries' income and population;[1] (2) factors indicating total potential demand of importing countries, such as importing countries' income and population; (3) factors representing the 'resistance' to a trade flow from a

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[1] Population as an explanatory variable of potential export supply may not be such a straightforward matter. Linnemann uses the ratio between production for the domestic market and production for the foreign market as an indicator and argues that a larger population tends to be associated with high domestic market/foreign market ratio due to economies of scale and diversification demands (1966: 12–14).

potential supplier to a potential buyer, such as geographic distance and other 'artificial' trade impediments.

The use of geographic distance to measure the natural obstacles to trade is controversial. Some suggest measuring the economic distance between countries on the basis of the difference between f.o.b. prices for particular commodities, as they can be calculated from the foreign trade statistics. However, Linnemann (1966) rejects this suggestion on the ground that this method would tend to underestimate differences in economic distance. This is simply because it can only be applied to (some) commodities actually traded between the countries concerned, but not to commodities which are not traded between them because of the very fact that transportation costs are too high. Also, three elements of natural trade obstacles, namely transport costs, transport time and economic horizon (or 'psychic distance'), are all clearly related to the distance between the two trading partners. Therefore, it is reasonable to use geographic distance as a 'proxy variable' for total natural trade impediments but one has to keep in mind that it not only stands for transportation costs but also for a variety of factors that together constitute obstacles to trade due to the existence of space.[2]

The basic gravity equation is given by

$$X_{ij} = \beta_0 (Y_i)^{\beta_1} (N_i)^{\beta_2} (Y_j)^{\beta_3} (N_j)^{\beta_4} (D_{ij})^{\beta_5} (ENV_i)^{\beta_6} (ENV_i)^{\beta_7} e_{ij} \qquad (5.1)$$

where X_{ij} is exports from country *i* to country *j*; (Y_i) and (Y_j) are GDP for exporting country *i* and importing country *j*; (N_i) and (N_j) are populations of countries *i* and

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[2] For a detailed discussion, see Linnemann (1966).

$j; D_{ij}$ is the geographical distance between countries *i* to *j;* (ENV_i) and (ENV_j) are environmental stringency indices developed by the World Bank; e_{ij} is a log normally distributed error term.

Since import tariffs are frequently argued to be either an ‘artificial’ obstacle to trade or new trade barriers that have emerged to offset the effects of more stringent environmental regulations, I extend the above model further to include variables of import tariffs both for reporting and partner countries. Equation (5.1) therefore is modified as

$$X_{ij} = \beta_0 (Y_i)^{\beta_1} (N_i)^{\beta_2} (Y_j)^{\beta_3} (N_j)^{\beta_4} (D_{ij})^{\beta_5} (ENV_i)^{\beta_6} (ENV_i)^{\beta_7} (DT_i)^{\beta_8} (DT_j)^{\beta_9} e_{ij} \tag{5.2}$$

where (DT_i) and (DT_j) are import tariffs of countries *i* and *j*, respectively.

Different versions of this gravity equation have been used in empirical studies. However, equation (5.1) is the most general version in the sense that it encompasses other more restricted gravity models. For example, Kalirajan and Shand (1998) do not include population in their equation but instead use GDP per capita. This is equivalent to placing the restriction that the coefficient on GDP and population are of equal value but the opposite sign. Tamirisa (1998) uses GDP per capita rather than GDP in his gravity equation analysis. Mathematically, this is essentially equation (5.1) after simple re-parameterisation.

To implement the empirical analysis, the above equations are modified by taking natural logs for both sides of the equations and the resulting estimated equations are log-linear as follows:

$$\begin{aligned}\ln(X_{ij}) = \alpha_0 + \beta_1 \ln(Y_i) + \beta_2 \ln(N_i) + \beta_3 \ln(Y_j) + \beta_4 \ln(N_j) +& \\ \beta_5 \ln(D_{ij}) + \beta_6 \ln(ENV_i) + \beta_7 \ln(ENV_i) + \varepsilon_{ij}&\end{aligned} \tag{5.3}$$

and

$$\begin{aligned}\ln(X_{ij}) = \alpha_0 + \beta_1 \ln(Y_i) + \beta_2 \ln(N_i) + \beta_3 \ln(Y_j) + \beta_4 \ln(N_j) + \beta_5 \ln(D_{ij}) +& \\ \beta_6 \ln(ENV_i) + \beta_7 \ln(ENV_i) + \beta_8 \ln(DT_i) + \beta_9 \ln(DT_j) + \varepsilon_{ij}&\end{aligned} \tag{5.4}$$

where $\alpha_0 = \ln(\beta_0)$ is the constant term that accounts for the effects of unmeasured trade distortions on exports and I leave the error term ε_{ij} to take care of all the possible measurement errors and ε_{ij} is assumed to be independently and identically distributed. The model can be estimated by the ordinary-least-squares method.

Data and measurement

Empirical implementation of the model described in the previous section requires data on bilateral total exports, bilateral exports of ESGs and bilateral exports of non-resource-based ESGs, gross domestic product (GDP), population, bilateral geographic distance, environmental stringency and import tariffs.

The major data constraint concerns the environmental stringency variable. Data for environmental stringency are generally not available, especially comparable cross-sectional data. Fortunately, I am able to make use of a set of unique environmental stringency indices recently developed by the World Bank. The World Bank's set of environmental stringency indices covers 31 countries. These indices measure the status of environmental policy and performance using a multidimensional survey of 31 national UNCED reports from Rio. These reports were compiled by each country on the basis of identical survey questions and clearly defined UNCED guidelines. The participation of non-government organisations (NGOs) in these surveys helps to assure us that the UNCED reports are not mere government handouts. These make a cross-country comparison possible (see Dasgupta *et al.* 1995). This set of indices encompasses many aspects of environmental policy and therefore can be used as the 'proxy variable' for environmental stringency. Since the survey considers the state of policy and performance in four environmental dimensions, namely, Air, Water, Land and Living Resources, the resulting environmental stringency index is a composite index of these four environmental dimension indices.

Unfortunately, some countries do not engage in bilateral trade with other sample countries. I therefore eliminate them from the sample. The resulting number of sample countries is 20. They are Bangladesh, Brazil, Bulgaria, China, Egypt, Finland, Germany, India, Ireland, Kenya, Korea, the Netherlands, Nigeria, Pakistan, the Philippines, South Africa, Switzerland, Thailand, Trinidad/Tobago and Tunisia. The model is estimated using cross-sectional data for these 20 countries in 1990 and there is a total of 361 observations.

The definition for ESGs has been discussed in detail in Chapter 3. Non-resource-based ESGs include 'iron and steel' (SITC 67), 'metal manufactures, n.e.s.' (SITC 69), 'cement' (SITC 661) and 'agricultural chemicals' (SITC 599). This definition is based on Low (1992) and UNIDO (1982) and is discussed by Van Beers and van den Bergh (1997).

Data on bilateral exports are obtained from the United Nation's COMTRADE database, available at the International Economic Data Bank of the Australian National University. Since current bilateral export data are subject to various distortions such as macroeconomic imbalance and inflation, I deflate export data in the period 1988 to 1992 using an export price index for each country obtained from the World Bank's World Development Indicator (1997). These data are then averaged over 1988-92. Bilateral trade data are in US$ '000.

Data on real GDP and population are obtained from Penn World Tables, Mark 5.6, by Summers and Heston (1991), available from the National Bureau of Economic Research online web site. Real GDP is in US$ billion while population is expressed in millions. Geographic distance is the direct-line distance between the capital cities of countries. It is measured in kilometres.

Since measurement of the intensity of non-tariff barriers is challenging, and the available measures are inadequate, I use explicit import tariffs to capture the border distortions. Therefore, in this study, the effects of non-tariff barriers (other than environmental stringency) are not measured separately but accounted for in the intercept (Tamirisa 1998 makes the same assumption). Import tariffs are measured as tariff revenue as a share of total imports and are obtained from the World Bank's World Development Indicator 1997.

Data for environmental stringency are obtained from Dasgupta, Mody, Roy and Wheeler (1995). The data belong to the family of index numbers, with the larger number indicating high stringency of environmental policy.

A list of summary statistics of the above variables, including mean, standard deviation, minimum, maximum and number of observations, is given in Table 5.1. Table 5.2 provides the correlation coefficient between variables. Most of the variables were not highly correlated, with the exception of GDP and population. High correlation between GDP and population may not be a serious problem since I can test the restriction that the coefficients of GDP and population are the same but of opposite sign. If this restriction is valid, I can use GDP per capita rather than GDP and population separately. Furthermore, what I am interested in is the sign and coefficient of the environmental regulation variable and those of the import tariff variable, rather than those of GDP or population. Since the variables are not highly correlated, the possibility of multicollinearity can be excluded.

Estimation results

The estimation of equation (5.3) in general will violate the statistical hypothesis of homoscedasticity since my sample countries differ greatly in terms of income and country size. The error terms associated with large countries might have variances much larger than the error terms associated with smaller countries. This may also be the case with income. I conduct various heteroscedasticity tests[3] and am able to

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[3] The results are not reported here but are available on request.

Table 5.1 Summary statistics for gravity-equation variables

	X_{ij}	Xd_{ij}	Xn_{ij}	Y_i	ENV_i	Dt_i	La_i	D_{ij}	Dt_j	Y_j	N_j	ENV_j	La_j
Mean	348183.7	82945.9	31671.3	301.4	630.2	13.9	1390.4	6530.5	14.0	290.6	141.6	618.0	1365.2
Standard Deviation	1676619.2	431684.4	158670.7	406.3	190.4	11.7	2665.7	3682.6	11.4	398.1	289.8	192.3	2596.8
Minimum	1.0	1.0	1.0	10.0	366.0	1.0	5.0	600.0	1.0	10.0	1.3	366.0	5.0
Maximum	19686350.0	5387058.0	2221034.0	1501.0	951.0	50.0	9326.0	17520.0	50.0	1501.0	1134.0	951.0	9326.0
Count	361	361	361	361	361	361	361	361	361	361	361	361	361

Source: Author's calculations.

Table 5.2 Correlations between gravity-equation variables

	X_{ij}	Xd_{ij}	Xn_{ij}	Dt_i	Y_i	N_i	ENV_i	D_{ij}	Dt_j	Y_j	N_j	ENV_j
X_{ij}	1.00											
Xd_{ij}	0.98	1.00										
Xn_{ij}	0.96	0.94	1.00									
Dt_i	-0.15	-0.15	-0.15	1.00								
Y_i	0.12	0.11	0.16	0.21	1.00							
N_i	-0.03	-0.03	-0.01	0.38	0.88	1.00						
ENV_i	0.23	0.22	0.22	-0.62	-0.06	-0.27	1.00					
D_{ij}	-0.20	-0.18	-0.17	0.03	0.03	0.02	-0.20	1.00				
Dt_j	-0.15	-0.13	-0.12	-0.05	-0.01	-0.02	0.03	0.03	1.00			
Y_j	0.09	0.09	0.08	-0.01	-0.05	-0.05	0.00	0.01	0.21	1.00		
N_j	-0.03	-0.02	0.00	-0.02	-0.05	-0.05	0.01	0.00	0.37	0.88	1.00	
ENV_j	0.22	0.20	0.18	0.03	0.00	0.01	-0.05	-0.19	-0.60	-0.02	-0.25	1.00

Source: Author's calculations.

reject the statistical assumption of homoscedasticity. In the light of this, I first make use of the White (1980) heteroscedasticity-consistent covariance matrix and calculate the t-value based on the corrected standard errors. The result is reported in Table 5.3. Furthermore, I implement the maximum likelihood estimation of equation (5.3) and (5.4) to correct possible 'dependent variable heteroscedasticity' (Prais and Houthakker 1955 and Theil 1971), with results reported in Appendix 5A and 5B.

Table 5.3 provides three versions of regressions for equation (5.3) with dependent variables using total bilateral exports ($\ln(X_{ij})$), bilateral exports of ESGs ($\ln(Xd_{ij})$) and bilateral exports of non-resource-based ESGs ($\ln(Xn_{ij})$), respectively. The results suggest that all coefficients have the expected signs in all three regressions. GDP in country i indicating the potential export supply and GDP in country j indicating the potential import demand are both found to be positive, and highly significant factors (at the 1 per cent level) in determining bilateral exports for the full sample. Parameters on population variables for the exporting countries are negative and significant, indicating that the greater the population the higher the domestic market–foreign market ratio. Coefficients of population variables for importing countries are negative but not significant for all three regressions. Coefficients of distance variables are negative and statistically significant at the 1 per cent level for all three equations, suggesting that the higher the transportation costs the lower the bilateral exports.

The coefficients of $\ln(ENV_i)$ are all positive and statistically significant at least at the 1 per cent level. This suggests that the hypothesis that more stringent environmental regulation will lower total bilateral exports, exports of ESGs and non-resource-based

ESGs exports can be rejected. I do not even find evidence to support the hypothesis that higher environmental regulations will lower exports of non-resource-based ESGs, an argument that has been frequently put forward on the basis that non-resource-based ESGs are footloose industries and respond significantly to changes in the stringency of environmental regulations.

To investigate whether new trade barriers emerge to offset the trade effects of more stringent environmental regulations and to disentangle the effects of environmental regulations and those of border distortions, I include import tariff variables and carry out a regression on equation (5.4). The results, with White's (1980) heteroscedasticity correction, are reported in Table 5.4. The overall coefficient significant tests using F-statistics are significant, ranging from 71.84 to 90.51 with (9, 351) degree freedom. Adjusted R-square values range from 0.64 to 0.69. Both GDP variables for exporting and importing countries and distance variables have the expected sign and are at least statistically significant at the 1 per cent level. Even then, high environmental stringency in exporting countries is not associated with lower total bilateral exports, lower ESGs exports or lower non-resource-based ESGs exports.

We find that partner countries' high import tariffs do reduce reporter countries' export performance in total bilateral exports, ESG exports and non-resource-based ESG exports, significant at least at the 1 per cent level. However, the hypothesis that new trade barriers emerge to offset the trade effects of higher stringency of environmental regulations cannot be accepted in the light of this test. Coefficients of import tariffs ($\ln(DT_i)$) for exporting countries appear to be positive but statistically insignificant.

Results from the dependent variable heteroscedasticity model using the maximum likelihood estimation technique, as shown in Appendix 5.1 and 5.2, reveal similar patterns. This suggests that my findings are rather robust.

I not only make use of the composite environmental stringency index in my regressions, but also carry out separate tests on equation (5.3) and (5.4) using each of the four dimensional environmental stringency variables, namely, Air, Water, Land and Living Resource indices. Results from these tests generally conform to the above findings (See Appendices 5.3–5.6). This is not surprising since there is a high correlation between these four dimensional environmental stringency variables.

Conclusion

In this chapter, two hypotheses are subjected to a multi-country empirical test using an extended gravity equation framework. The first is whether countries with more stringent environmental regulations lower their exports of ESGs and/or non-resource-based ESGs. The second hypothesis is whether new trade barriers emerge to offset the trade effects of more stringent environmental policies. To test this hypothesis, I am able to make use of a unique set of comparative environmental stringency indices recently developed by the World Bank.

Our results reject the above two hypotheses, suggesting that countries with higher stringency of environmental regulations do not reduce their exports of ESGs and/or non-resource-based ESGs, and that new trade barriers do not emerge to offset the trade effects of more stringent environmental policy in any statistically significant way. My findings are robust compared with alternative versions of heteroscedasticity correction estimations and alternative environmental dimension indices such as the Air, Water, Land and Living Resource indices also developed by the World Bank.

An implication of this study is that the trade effects of domestic environmental policy may not well be understood if one confines oneself to the static factor endowment theory. Technological innovation, together with other factors, may be more important in determining the export performance of ESGs. A recent study by Berman and Bui (1998), using firm-level data, shows that more stringent air quality regulation results in an increase in productivity levels in petroleum refining in the United States. They conclude that abatement investments are productive. My results are consistent with their findings and should help refocus the environmental competitiveness debate.

However, a theoretical model that discusses the linkage between environmental factor endowment, technological innovation and growth in a dynamic context is necessary. This is a theme that I shall now turn to in Chapter 6.

Table 5.3 Regression results of extended gravity model (Equation (5.3))

Trade flows	$\ln(X_{ij})$	$\ln(Xd_{ij})$	$\ln(Xn_{ij})$
$\ln(Y_i)$	1.61 (6.32)**	2.38 (8.54)**	3.09 (10.58)**
$\ln(N_i)$	-0.43 (-1.89)*	-1.13 (-4.47)**	-1.31 (-5.10)**
$\ln(Y_j)$	1.00 (4.82)**	1.11 (3.78)**	1.16 (3.94)**
$\ln(N_j)$	-0.09 (-0.45)	-0.07 (-0.26)	-0.38 (-1.47)
$\ln(D_{ij})$	-0.90 (-7.86)**	-0.92 (-6.39)**	-0.81 (-4.66)**
$\ln(ENV_i)$	2.32 (3.42)**	2.86 (3.51)**	2.60 (3.05)**
$\ln(ENV_j)$	1.67 (2.63)**	0.87 (1.04)	0.61 (0.70)
Constant	-18.72 (-2.93)**	-21.0 (-2.77)**	-22.22 (-2.62)**
Log-likelihood	-695.09	-789.23	-795.43
R^2 adjusted	0.665	0.629	0.67
F-statistic	103.24	88.13	105.41
Number of observations	361	361	361

Notes: ** denotes significant at the 1% level; * denotes significant at the 5% level. Figures in parentheses are t-ratios.
Source: Author's calculations.

Table 5.4 Regression results of extended gravity model (Equation (5.4))

Trade flows	ln (X_{ij})	ln (Xd_{ij})	ln (Xn_{ij})
ln (Y_i)	1.55	2.32	3.04
	(5.88)**	(8.01)**	(10.33)**
ln (N_i)	-0.38	-1.08	-1.27
	(-1.63)	(-4.19)**	(-4.96)**
ln (Y_j)	0.85	0.90	0.85
	(4.07)**	(3.05)**	(2.98)**
ln (N_j)	0.03	0.10	-0.13
	(0.18)	(0.37)	(-0.53)
ln (D_{ij})	-0.91	-0.94	-0.83
	(-8.29)**	(-6.76)**	(-5.07)**
ln (ENV_i)	1.98	2.48	2.28
	(2.84)**	(2.92)**	(2.52)**
ln (ENV_j)	0.77	-0.30	-1.15
	(1.14)	(-0.35)	(-1.27)
ln (DT_i)	-0.17	-0.18	-0.15
	(-1.39)	(-1.21)	(-0.88)
ln (DT_j)	-0.46	-0.60	-0.91
	(-3.57)**	(-3.38)**	(-5.22)**
Constant	-8.81	-8.74	-5.68
	(-1.30)	(-1.05)	(-0.60)
Log-likelihood	-688.83	-783.14	-782.44
R^2 adjusted	0.67	0.64	0.69
F-statistic	84.04	71.84	90.51
Number of observations	361	361	361

Notes: ** denotes significant at the 1% level; * denotes significant at the 5% level. Figures in parentheses are t-ratios.

Source: Author's calculations.

Appendix 5.1 Heteroskedasticity model of extended gravity equation (Equation (5.3))

Trade flows	ln (X_{ij})	ln (Xd_{ij})	ln (Xn_{ij})
ln (Y_i)	1.10 (5.15)**	2.52 (11.99)**	3.50 (40.03)**
ln (N_i)	-0.07 (-0.37)	-1.63 (-7.67)**	-1.44 (-22.32)**
ln (Y_j)	0.70 (3.13)**	1.10 (4.20)**	1.20 (18.84)**
ln (N_j)	0.22 (1.10)	-0.08 (-0.40)	-0.38 (-8.12)**
ln (D_{ij})	-0.90 (-5.55)**	-0.79 (-3.63)**	-0.83 (-11.39)**
ln (ENV_i)	2.90 (4.63)**	0.99 (1.25)	2.78 (6.76)**
ln (ENV_j)	2.35 (3.65)**	-0.18 (-0.27)	0.63 (4.32)**
Constant	-25.24 (-3.87)**	-2.69 (-0.34)	-24.39 (-8.37)**
Log-likelihood	-766.38	-907.50	-5956.39
R^2 adjusted	0.663	0.61	0.675
Number of observations	361	361	361

Notes: ** denotes significant at the 1% level; * denotes significant at the 5% level. Numbers are estimated asymptotic coefficients except otherwise indicated. Figures in parentheses are asymptotic t-ratios. Results are obtained using quasi-Newton method.

Source: Author's calculations.

Appendix 5.2 Heteroskedasticity model of extended gravity equation (Equation (5.4))

Trade flows	$\ln(X_{ij})$	$\ln(Xd_{ij})$	$\ln(Xn_{ij})$
$\ln(Y_i)$	1.09 (5.04)**	2.75 (13.06)**	3.36 (34.79)**
$\ln(N_i)$	-0.07 (-0.36)	-1.93 (-8.99)**	-1.32 (-17.83)**
$\ln(Y_j)$	0.58 (2.55)**	0.85 (3.23)**	0.93 (11.48)**
$\ln(N_j)$	0.31 (1.61)	0.11 (0.54)	-0.19 (-2.76)**
$\ln(D_{ij})$	-0.91 (-5.68)**	-0.66 (-3.15)**	-0.78 (-9.45)**
$\ln(ENV_i)$	2.38 (3.37)**	-0.31 (-0.34)	3.21 (5.73)**
$\ln(ENV_j)$	1.51 (2.14)**	-1.22 (-1.73)	-1.37 (-6.94)**
$\ln(DT_i)$	-0.20 (-1.20)	-0.09 (-0.44)	0.39 (2.20)**
$\ln(DT_j)$	-0.45 (-2.74)**	-0.72 (-3.50)**	-0.89 (-12.20)**
Constant	-14.68 (-1.97)**	13.44 (1.52)	-12.98 (-2.97)**
Log-likelihood	-762.66	-910.49	-2797.87
R^2 adjusted	0.676	0.60	0.685
Number of observations	361	361	361

Notes: ** denotes significant at the 1% level; * denotes significant at the 5% level. Numbers are estimated asymptotic coefficients except otherwise indicated. Figures in parentheses are asymptotic t-ratios. Results are obtained using quasi-Newton method.

Source: Author's calculations.

Appendix 5.3 Regression results of extended gravity model (Equation (5.4)): Air quality regulation as an environmental stringency variable

Trade flows	ln (X_{ij})	ln (Xd_{ij})	ln (Xn_{ij})
ln (Y_i)	1.32 (4.21)**	2.28 (6.47)**	3.09 (8.86)**
ln (N_i)	-0.18 (-0.63)	-1.06 (-3.29)**	-1.34 (-4.29)**
ln (Y_j)	0.64 (2.47)**	0.84 (2.45)**	0.88 (2.65)**
ln (N_j)	0.22 (0.90)	0.15 (0.52)	-0.15 (-0.54)
ln (D_{ij})	-0.86 (-7.74)**	-0.94 (-6.59)**	-0.85 (-5.06)**
ln (ENV_i)	2.07 (3.00)**	1.80 (2.16)*	1.34 (1.57)**
ln (ENV_j)	1.15 (1.78)	-0.01 (-0.02)	-0.87 (-1.08)
ln (DT_i)	-0.19 (-1.61)	-0.26 (-1.82)	-0.25 (-1.52)
ln (DT_j)	-0.45 (-3.68)**	-0.58 (-3.30)**	-0.87 (-5.12)**
Constant	-6.63 (-1.35)	-3.13 (-0.52)	-0.48 (-0.71)
Log-likelihood	-687.05	-785.09	-785.14
R^2 adjusted	0.68	0.64	0.69
F-statistic	85.26	70.64	88.59
Number of observations	361	361	361

Notes: ** denotes significant at the 1% level; * denotes significant at the 5% level. Figures in parentheses are t-ratios (White's heteroskedasticity corrected).
Source: Author's calculations.

Appendix 5.4 Regression results of extended gravity model (Equation (5.4)): Water quality regulation as an environmental stringency variable

Trade flows	$\ln(X_{ij})$	$\ln(Xd_{ij})$	$\ln(Xn_{ij})$
$\ln(Y_i)$	1.69 (6.77)**	2.37 (8.82)**	3.05 (11.00)**
$\ln(N_i)$	-0.49 (-2.18)*	-1.09 (-4.45)**	-1.24 (-5.01)**
$\ln(Y_j)$	0.83 (4.27)**	0.88 (3.20)**	0.75 (2.83)**
$\ln(N_j)$	0.06 (0.32)	0.12 (0.48)	-0.05 (-0.21)
$\ln(D_{ij})$	-0.92 (-8.28)**	-0.92 (-6.70)**	-0.79 (-4.87)**
$\ln(ENV_i)$	1.48 (2.24)*	2.52 (3.09)**	2.54 (2.91)**
$\ln(ENV_j)$	0.93 (1.43)	-0.21 (-0.26)	-0.78 (-0.90)
$\ln(DT_i)$	-0.22 (-1.87)	-0.19 (-1.28)	-0.14 (-0.84)
$\ln(DT_j)$	-0.45 (-3.53)**	-0.60 (-3.36)**	-0.88 (-5.09)**
Constant	-3.60 (-0.69)	-6.74 (-1.04)	-7.62 (-1.03)
Log-likelihood	-690.07	-782.45	-781.42
R^2 adjusted	0.67	0.64	0.69
F-statistic	83.19	72.25	91.24
Number of observations	361	361	361

Notes: ** denotes significant at the 1% level; * denotes significant at the 5% level. Figures in parentheses are t-ratios (White's heteroskedasticity corrected).
Source: Author's calculations.

Appendix 5.5 Regression results of extended gravity model (Equation (5.4)): Land quality regulation as an environmental stringency variable

Trade flows	ln (X_{ij})	ln (Xd_{ij})	ln (Xn_{ij})
ln (Y_i)	1.65 (6.62)**	2.46 (8.73)**	3.16 (11.08)**
ln (N_i)	-0.47 (-2.19)*	-1.21 (-4.91)**	-1.39 (-5.65)**
ln (Y_j)	0.97 (4.93)**	0.94 (3.26)**	0.87 (3.15)**
ln (N_j)	-0.08 (-0.44)	0.05 (0.22)	-0.15 (-0.63)
ln (D_{ij})	-0.95 (-8.60)**	-0.97 (-7.02)**	-0.85 (-5.28)**
ln (ENV_i)	1.79 (2.46)**	2.16 (2.30)*	2.03 (2.07)**
ln (ENV_j)	0.25 (0.34)	-0.60 (-0.63)	-1.46 (-1.50)
ln (DT_i)	-0.19 (-1.60)	-0.23 (-1.50)	-0.19 (-1.09)
ln (DT_j)	-0.51 (-3.89)**	-0.62 (-3.49)**	-0.92 (-5.30)**
Constant	-1.43 (-0.25)	-2.56 (-0.36)	-1.19 (-0.14)
Log-likelihood	-690.58	-784.53	-783.36
R^2 adjusted	0.67	0.64	0.69
F-statistic	82.85	70.98	89.85
Number of observations	361	361	361

Notes: ** denotes significant at the 1% level; * denotes significant at the 5% level. Figures in parentheses are t-ratios (White's heteroskedasticity corrected).

Source: Author's calculations.

Appendix 5.6 Regression results of extended gravity model (Equation (5.4)): Living Resource quality regulation as an environmental stringency variable

Trade flows	ln (X_{ij})	ln (Xd_{ij})	ln (Xn_{ij})
ln (Y_i)	1.57 (6.52)**	2.33 (9.02)**	3.06 (11.55)**
ln (N_i)	-0.42 (-2.07)*	-1.12 (-5.10)**	-1.32 (-5.96)**
ln (Y_j)	0.93 (5.06)**	0.91 (3.34)**	0.84 (3.21)**
ln (N_j)	-0.05 (-0.29)	0.09 (0.40)	-0.11 (-0.52)
ln (D_{ij})	-0.94 (-8.68)**	-0.95 (-6.87)**	-0.83 (-5.31)**
ln (ENV_i)	1.99 (3.36)**	2.57 (3.50)*	2.31 (2.98)**
ln (ENV_j)	0.42 (0.73)	-0.38 (-0.50)	-1.22 (-1.51)
ln (DT_i)	-0.13 (-1.08)	-0.13 (-0.86)	-0.11 (-0.63)
ln (DT_j)	-0.48 (-3.61)**	-0.62 (-3.42)**	-0.94 (-5.36)**
Constant	-3.21 (-0.70)	-5.69 (-0.99)	-3.84 (-0.58)
Log-likelihood	-687.69	-781.42	-780.82
R^2 adjusted	0.68	0.64	0.69
F-statistic	84.82	72.89	91.68
Number of observations	361	361	361

Notes: ** denotes significant at the 1% level; * denotes significant at the 5% level. Figures in parentheses are t-ratios (White's heteroskedasticity corrected).
Source: Author's calculations.

6 Environmental Regulation, Technological Innovation and Economic Growth: A Theoretical Model

Introduction

Many developing countries have long seen environmental regulations and economic development as mutually exclusive. According to this view, to achieve rapid economic development and secure international competitiveness in environmentally sensitive industries, domestic environmental standards should not be stringent. To the extent that the environment has assumed a growing importance, this can be postponed until a high income level has been achieved. This perception has received considerable support from static cost-benefit analysis.

This chapter provides an alternative view on this issue. It attempts to formalise a simple model in which the more fundamental, dynamic determinant of a country's long-run growth is its capacity for technology innovation. The physical setup of this model is basically along the lines of recent endogenous growth literature, especially Uzawa (1965), Lucas (1988) and Rebelo (1991). Three key features characterise the model. First, it is based on the intertemporal optimisation of representative agents in the economy. Second, ESGs are modelled as an intermediate good which is used in the production of final consumption goods. Third, R&D takes place by means of a linear technology and is sector-specific (to the intermediate goods sector). Firms with an R&D sector therefore have to make decisions about the allocation of the dynamic factor that can be accumulated. With the production function exhibiting constant returns to scale in the factor that is accumulated, the equilibrium is characterised by endogenous growth.

Two important issues can be addressed using this framework. First, what are the effects of environmental regulation on long-run growth? Second, how important is technological innovation to a country's growth? The basic findings are that, (1) changes in the stringency of environmental regulations do not have long-run growth effects; (2) technological innovation is important in determining a country's long-run growth.

The limitation of the model is obvious. Since it is a closed economy model, the extension to trade is not addressed explicitly and neither are the trade effects of environmental policy. Nevertheless, it does provide a simple framework to address the issue of environmental regulation, technological innovation and a country's long-run growth. This is important for countries, especially developing countries, facing the choice of appropriate development strategy.

The remainder of the chapter is organised as follows. The next section is the basic setup of the model in the context of a central planned economy. Section 3 examines the equilibrium, Section 4 looks into balanced growth path and analyses the effects of environmental regulation. Section 5 provides a version of this model for a decentralised economy. The last section provides a conclusion.

The basic model: the central planner's problem

Preferences

Consider an economy where there is an infinitely-lived representative household whose intertemporal problem is to choose the level of consumption Y to maximise the sum of all its future flows of discounted utility over an unbounded horizon subject to an equation of motion of private wealth, A. The utility function is assumed to be increasing in Y and strictly concave: $U^{'}(Y) > 0$ and $U^{''}(Y) < 0$. The concavity assumption generates a consumption-smoothing profile. $U(Y)$ is also assumed to satisfy the Inada conditions: $U^{'}(Y) \rightarrow \infty$ as $Y \rightarrow 0$, and $U^{'}(Y) \rightarrow 0$ as $Y \rightarrow \infty$. To obtain a closed form solution, we further assume the utility function has the following isoelastistic form:

$$U(Y_t) = \int_t^{\infty} e^{-\rho t} \frac{Y_t^{1-\varphi} - 1}{1-\varphi} dt \qquad (6.1)$$

This is known as the *constant intertemporal elasticity of substitution* (CIES) utility function and is widely used in the endogenous growth literature because it permits an easy solution. The elasticity of substitution for this utility function is the constant $\sigma = 1/\varphi$. A higher φ implies a lower willingness to substitute intertemporally. ρ is the subjective discount rate.

Production

There are two factors of production: the environment[1] and human capital. Production includes two sectors: final goods production using as its inputs the environment factor and the intermediate good; and intermediate goods production using as its inputs the environment factor and human capital. The production function for each sector can be written explicitly as follows.

1) Final goods sector:

$$Y = E_1^{1-\alpha} X^{\alpha} \qquad (6.2)$$

where Y denotes output of final goods, E_1 is the input of the environment factor in the final goods sector and X is the output of intermediate goods. Subscript t is omitted hereafter for simplicity.

2) For the intermediate goods sector:

$$X = E_2^{1-\beta} (\theta H)^{\beta} \qquad (6.3)$$

Where E_2 is the input of the environment factor in the intermediate goods sector, H is the amount of skill level per worker and $\theta \in [0,1]$ is the fraction of human capital devoted to the production process. The intermediate goods sector is assumed to be the

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[1] It may be rather difficult to think of the environment as a of factor of production. The following two explanations might be helpful. First, imagine a country sets up a targeted emission quota (it can be set up by internal or external demand as at the 1997 Kyoto conference) which is subsequently distributed among the major polluters in the country and there is a tradable permit market for these quotas within national borders. The price of the quota, therefore, can be regarded as the cost of environment factor input. The other way to think about it is that emission reduction implies more abatement activity and less conventional inputs available for the production of goods. Reductions in E, the environment factor, therefore, result in reduced output (For the latter interpretation, see also Cropper and Oates (1992)).

environmentally sensitive goods sector since most of the ESG sectors 'tend to be basic industries, often involved in the processing of raw materials (chemicals, pulp and paper, refineries)' (Siebert *et al.* 1980). Its output is used to produce the final consumption good and it has an R&D sector attached.

Following Uzawa (1965) and Lucas (1988), endogenous growth is modelled through human capital formation that takes place within the firm. I assume that at each point in time, production in the intermediate goods sector is endowed with a certain stock of human capital. This is a crucial departure from the existing literature. Since human capital is assumed to be firm-specific, it can either be used as an additional factor of production of intermediate goods or as input to increase the existing human capital stock.

$$\dot{H} = A \cdot (1-\theta) \cdot H \qquad (6.4)$$

where A is a positive productivity parameter. The environmental factor supply of this economy is fixed and is subject to changes by governmental environmental regulations. Therefore, we have

$$E = E_1 + E_2 \qquad (6.5)$$

This completes the basic setup of the model.

Equilibrium

The intertemporal choice facing the planner is

$$\operatorname{Max} U(Y_t) = \int_t^{\infty} e^{-\rho t} \frac{Y_t^{1-\varphi} - 1}{1-\varphi} dt \qquad (6.6)$$

Subject to. (6.2), (6.3), (6.4) and (6.5)

The current-value Hamiltonian is given by

$$J = \frac{Y^{1-\varphi} - 1}{1-\varphi} + \lambda[A(1-\theta)H] + \xi_1 \cdot (E_1^{1-\alpha} X^{\alpha} - Y) + \xi_2 \cdot [E_2^{1-\beta} (\theta H)^{\beta} - X] + \xi_3 \cdot (E - E_1 - E_2) \qquad (6.7)$$

where λ is the shadow price of human capital and ξ_1 , ξ_2 and ξ_3 are the shadow prices of final consumption goods *Y*, intermediate goods *X* and environmental input *E*. Solving the optimal conditions for control variables, *Y*, *X*, E_1, E_2 and *θ*, and for the state variable *H* gives the following six first order conditions.

$$Y^{-\varphi} = \xi_1 \qquad (6.8)$$

$$\xi_1 \cdot (1-\alpha) \cdot E_1^{-\alpha} (X)^{\alpha} = \xi_3 \qquad (6.9)$$

$$\xi_2 (1-\beta) E_2^{-\beta} (\theta H)^{\beta} = \xi_3 \qquad (6.10)$$

$$\xi_1 \cdot \alpha E_1^{1-\alpha} (X)^{\alpha-1} = \xi_2 \qquad (6.11)$$

$$\xi_2 \beta E_2^{1-\beta} \theta^{\beta-1} H^{\beta} = \lambda A H \qquad (6.12)$$

$$\rho = \frac{\dot{\lambda}}{\lambda} + \frac{\xi_2 \beta E_2^{1-\beta} \theta^{\beta} H^{\beta-1}}{\lambda} + A(1-\theta) \qquad (6.13)$$

Equation (6.12) states that in equilibrium, the marginal product of human capital must be equally valued in production and in human capital accumulation. Equations (6.9) and (6.10) state that the marginal product of the environment factor in each production sector should be equal to its shadow price, ξ_3. Equation (6.13) states that in equilibrium, the subjective discount rate equals capital gains, $\dot{\lambda}/\lambda$, plus the marginal productivity of human capital in production and in 'schooling'. The transversality condition is

$$\lim_{t\to\infty}[\lambda(t)\cdot H(t)\cdot \exp(-\rho t)] = 0 \qquad (6.14)$$

Substituting (6.12) into (6.13) gives

$$\frac{\dot{\lambda}}{\lambda} = \rho - A \qquad (6.15)$$

Equation (6.15) implies that the shadow price of human capital changes at a constant rate, (ρ - A). Combining equations (6.14) and (6.15), the transversality condition becomes

$$\lim_{t\to\infty}[H(t)\cdot \exp^{-At}] = 0 \qquad (6.16)$$

We can see that the transversality condition holds exactly. Equation (6.16) also implies that the quantity of human capital *H (t)* does not grow asymptotically at a rate higher than *A*. It would be suboptimal for the central planner to accumulate human capital forever at a rate higher than *A*, because utility would increase if this human capital were instead put into production at some finite time.

Now, we can solve for the equilibrium allocation of the environmental factor between two sectors, final goods and intermediate goods sectors. Dividing (6.9) by (6.11) and making use of equation (6.10), we obtain the following equations:

$$E_1 = \frac{1-\alpha}{1-\alpha\beta} \cdot E \qquad (6.17)$$

$$E_2 = \frac{\alpha \cdot (1-\beta)}{1-\alpha\beta} \cdot E \qquad (6.18)$$

The equilibrium allocation of the environmental factor between two sectors E_i/E is constant and independent of E.

Balanced growth paths

We can now derive the balanced growth paths of Y, X and H, respectively. From equations (6.9), (6.10) , (6.11) and (6.12), the following function can be derived:

$$\lambda A \cdot (\theta H) = \alpha\beta \cdot Y^{1-\varphi} \qquad (6.19)$$

Substituting equation (6.2) and (6.3) into (6.19) gives the following relation between stringency, E and the input of human capital into intermediate goods sector, (θH).

$$\theta H = \left[\frac{K}{\lambda A}\right]^{1/1-\alpha\beta(1-\varphi)} \cdot E^{(1-\alpha\beta)(1-\varphi)/(1-\alpha\beta(1-\varphi))} \qquad (6.20)$$

where $K = \alpha\beta \cdot \left(\frac{1-\alpha}{1-\alpha\beta}\right)^{(1-\alpha)(1-\varphi)} \left(\frac{\alpha(1-\beta)}{1-\alpha\beta}\right)^{\alpha(1-\alpha)(1-\varphi)}$ is a positive constant. Taking natural logarithms and totally differentiating equation (6.20) with respect to time *t* yields

$$\hat{(\theta H)} = \left(-\,{}^{1}\!\big/_{(1-\alpha\beta(1-\varphi))}\right) \cdot \hat{\lambda} \qquad (6.21)$$

Note that on the balanced growth path, $\hat{\theta} = 0$. Since λ grows at a constant rate (ρ - A) while *H* grows at rate *A*(1-*θ*) along the balanced growth path, one can readily solve for the equilibrium value of *θ*.

$$\theta = \frac{\rho - \alpha\beta(1-\varphi)A}{A(1-\alpha\beta(1-\varphi))} \qquad (6.22)$$

This gives the result that on the balanced growth path, changes in *E* do not affect the sectoral allocation of human capital between the production of intermediate goods and the R&D sector. Having solved the equilibrium value of *θ*, we can now examine the effects of changes in the stringency of environmental regulation on output growth of ESGs and ENSGs (environmentally non-sensitive goods). Dividing (6.2) by (6.3) and making use of equation (6.22) gives the following equation:

$$\frac{Y}{X} = \eta \cdot E^{\beta(1-\alpha)} \cdot (\theta H)^{\beta(\alpha-1)} \qquad (6.23)$$

where $\eta = \dfrac{\left(\alpha(1-\beta)\big/(1-\alpha\beta)\right)^{(\alpha-1)(1-\beta)}}{\left((1-\alpha)\big/(1-\alpha\beta)\right)^{(\alpha-1)}}$ is a positive constant. It follows that along the balanced growth path,

$$\frac{d(\frac{Y}{X})}{dE} \geq 0 \qquad (6.24)$$

Equation (6.24) states that in equilibrium the effects of changes in the stringency of environmental regulations on the relative output growth of ENSGs to the ESG sector is positive. To put it another way, an increase in environmental stringency (a reduction of *E*) will lead to a higher output of ESGS relative to ENSGs. (Note that this result can also be derived in a static version of this model.)

Although changes of environmental supply have level effects on the output of final goods, the long-run growth rate of final goods will not be affected by changes in environmental supply in this economy. To see this, one can take natural logarithms and totally differentiate equation (6.19). This gives

$$\hat{Y} = \frac{\alpha\beta(A-\rho)}{1-\alpha\beta(1-\varphi)} \qquad (6.25)$$

Some properties are worth noting. First, changes in *E* do not have a long-run effect on growth. Second, the rate of growth is higher the greater the productivity of human capital accumulation *A*. Third, the rate of growth is higher the greater the elasticity of intertemporal substitution ($1/\sigma$). Fourth, the rate of growth is higher the lower the pure rate of time preference (ρ).

The decentralised economy

The above problem can also be analysed in the context of a decentralised economy. Since there is no externality at all in the above economy, one would expect the result in a decentralised economy would be the same as that for a central planner.

Imagine there is an infinitely-lived representative household whose intertemporal problem is essentially that of the central planner in this decentralised economy. The household is assumed to be endowed with a certain amount of the environmental factor and lends to two production sectors at competitive price ε. $A(t)$ is the household's assets at time t. Y and X denotes the output of final consumption goods and intermediate goods respectively. P_y and P_x are the prices of final goods and the intermediate goods sector. This representative household maximises its utility as given in equation (6.1) subject to the following budget constraint:

$$\dot{A} = rA + \varepsilon \cdot E - P_y \cdot Y \qquad (6.26)$$

where r is the real interest rate. The current value Hamiltonian is given by

$$J = \frac{Y^{1-\varphi} - 1}{1-\varphi} + \mu(rA + \varepsilon E - P_y Y) \qquad (6.27)$$

where μ is the present value shadow price of an additional unit of income. The first order condition for this problem is given by

$$Y^{-\varphi} = \mu \cdot P_y \tag{6.28}$$

$$\rho \cdot \mu - \dot{\mu} = \mu A \tag{6.29}$$

Equation (6.28) may be arranged as

$$\frac{\dot{\mu}}{\mu} = \rho - A \tag{6.30}$$

or alternatively

$$\mu(t) = \mu(0) \cdot e^{(\rho - A)t} \tag{6.31}$$

Faced with an intertemporal choice, the representative intermediate goods producer seeks to maximise

$$\int_0^{\infty} \left[P_x E_2^{1-\beta} (\theta H)^{\beta} - \varepsilon E_2 \right] \cdot e^{-rt} dt \tag{6.32}$$

Subject to $\dot{H} = A \cdot (1 - \theta) \cdot H$

The current-value Hamiltonian is given by

$$J = \left[P_x E_2^{1-\beta} (\theta H)^{\beta} - \varepsilon E_2 \right] + \lambda \left[A(1-\theta) H \right] \tag{6.33}$$

where λ is the shadow price of an additional unit of human capital and ε the factor price of the environment input. Solving the optimal conditions for control variables, E and θ, and for the state variable H gives the following three first-order conditions.

$$\beta P_x E_2^{1-\beta} \theta^{\beta-1} H^{\beta} = \lambda A H \tag{6.34}$$

$$(1-\beta) P_x E_2^{-\beta} (\theta H)^{\beta} = \varepsilon \tag{6.35}$$

$$r = \frac{\dot{\lambda}}{\lambda} + \frac{\beta P_x E_2^{1-\beta} \theta^{\beta} H^{\beta-1}}{\lambda} + A(1-\theta) \tag{6.36}$$

Equation (6.34) states that in equilibrium, the marginal product of human capital must be equally valued in production and in human capital accumulation. Equation (6.35) states that the marginal product of the environment factor should be equal to its market price ε. Equation (6.36) states that the return on accumulated capital equals capital gains, $\dot{\lambda}/\lambda$, plus the marginal productivity of human capital in production and in 'schooling'.

The representative final goods sector firm seeks to maximise its life-time profit

$$\pi = \int_0^{\infty} \left(P_y \cdot E_1^{1-\alpha} \cdot X^{\alpha} - \varepsilon \cdot E - P_x \cdot X \right) \cdot e^{-rt} dt \tag{6.37}$$

The first-order condition to this problem is given by

$$(1-\alpha) \cdot P_y \cdot E_1^{-\alpha} X^{\alpha} = \varepsilon \tag{6.38}$$

$$\alpha \cdot P_y \cdot E_1^{1-\alpha} \cdot X^{\alpha-1} = P_x \tag{6.39}$$

Sectoral allocation of environmental input E can be solved readily as that in the central planner's problem. This gives

$$E_1 = \frac{1-\alpha}{1-\alpha\beta} \cdot E \qquad (6.40)$$

$$E_2 = \frac{\alpha \cdot (1-\beta)}{1-\alpha\beta} \cdot E \qquad (6.41)$$

The solution for the effects of E on sectoral allocation of human capital is given by combining equation (6.34), (6.39) and (6.28). From equation (6.34), we can see that

$$\lambda A(\theta H) = \alpha\beta \cdot ({}^{1}\!/_{\mu}) \cdot Y^{1-\varphi} \qquad (6.42)$$

Therefore

$$\theta H = \left[\frac{K}{\mu\lambda A} \right]^{1/1-\alpha\beta(1-\varphi)} \cdot E^{(1-\alpha\beta()(1-\varphi)/(1-\alpha\beta(1-\varphi)} \qquad (6.43)$$

where $K = \alpha\beta \cdot \left(\frac{1-\alpha}{1-\alpha\beta} \right)^{(1-\alpha)(1-\varphi)} \left(\frac{\alpha(1-\beta)}{1-\alpha\beta} \right)^{\alpha(1-\alpha)(1-\varphi)}$ is a positive constant.

Note that on the balanced growth path, $\hat{\theta} = 0$. Since λ grows at constant rate (ρ - A) while H grows at rate A(1-θ) along the balanced growth path one can readily solve the equilibrium value of θ:

$$\theta = \frac{\rho - \alpha\beta(1-\varphi)A}{A(1-\alpha\beta(1-\varphi))} \qquad (6.44)$$

This gives the same result as that in the centralised economy that on a balanced growth path, changes in E do not affect the sectoral allocation of human capital between the production of intermediate goods and the R&D sector. Having solved the equilibrium value of θ, we can now illustrate the effects of environmental regulations on relative output of ESGs and ENSGs, by dividing equation (6.2) by (6.3). This gives

$$\frac{Y}{X} = \eta \cdot E^{\beta(1-\alpha)} \cdot (\theta H)^{\beta(\alpha-1)} \qquad (6.45)$$

where $\eta = \dfrac{\left(\alpha(1-\beta) \big/ (1-\alpha\beta)\right)^{(\alpha-1)(1-\beta)}}{\left((1-\alpha) \big/ (1-\alpha\beta)\right)^{(\alpha-1)}}$ is a positive constant. It follows that along the balanced growth path,

$$\frac{d(\frac{Y}{X})}{dE} \geq 0 \qquad (6.46)$$

Equation (6.46) states that in equilibrium the effects of changes in the stringency of environmental regulations on the relative output growth of ENSGs to the ESG sector is positive. To put it another way, an increase in the stringency of environmental stringency (a reduction of E) will lead to a higher output of ESGs relative to ENSGs.

Although changes in environmental supply have level effects on the output of final goods, the long-run rate of growth of final goods, however, will not be affected by changes in environmental supply in this economy. To see this, one can take natural logarithm and totally differentiate equation (6.42). This gives

$$\hat{Y} = \frac{\alpha\beta(A-\rho)}{1-\alpha\beta(1-\varphi)} \tag{6.47}$$

We thus obtain the same properties as in the centralised economy.

Conclusion

In this chapter, a simple intertemporal optimisation problem is set up to address the effects of environmental policy and technological innovation on a country's long-run growth. There are two sectors, a final goods sector which is ENSGs, and an intermediate goods sector which is assumed to be ESGs. R&D activity is assumed to be sector specific. There are two factors, an environment factor and human capital. The basic findings are that, (1) changes in the stringency of environmental regulations do not have long-run growth effects; (2) technological innovation is important in determining a country's long-run growth.

The limitation of the model is obvious. Since it is a closed economy model, the extension to trade is not addressed explicitly and neither are the trade effects of environmental policy. Nevertheless, it does provide a simple framework to address the issue of environmental regulation, technological innovation and a country's long-run growth. This is important for those countries, especially developing countries, when facing the choice of appropriate development strategy. Many developing countries have long seen environmental regulations and economic development as mutually exclusive. To the extent that the environment has assumed a growing importance, this can be postponed until a high income level has been achieved. This perception has received considerable support from static cost-benefit analysis. Interestingly, this chapter has provided an alternative view on this issue. That is, changes in the stringency of environmental regulations do not have long-run growth effects, while technological innovation has. There can be a compromise between environment and growth.

In the next chapter, the effects of technology factor on the international competitiveness of ESGs will be tested explicitly.

7 International Trade and Environmental Policy: The Role of Technology and Effectiveness of 'Eco-Dumping'

Time-series studies in Chapters 3 and 4 suggest that trade patterns of ESGs did not undergo systematic change during the last three decades. One plausible explanation for this is that technological innovation may play an important role in determining international competitiveness. Environmental regulation may be productivity enhancing, as suggested in a recent study by Berman and Bui (1998) using plant level data. The theoretical discussion in Chapter 6 also identified the importance of technological innovation as a factor in economic growth. In this chapter, I investigate the significance of the technology factor in determining the international competitiveness of environmentally sensitive industries in the context of policy debate over 'eco-dumping'.

Introduction

A country is regarded as engaging in 'ecological-dumping',[1] or 'eco-dumping', when it gains international competitiveness in environmentally sensitive industries by imposing relatively lax environmental standards on the production of a good. More precisely, 'eco-dumping' can be defined as a policy which 'prices

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[1] When a firm sells products in another country at prices below average cost or below the price in the home country, it is called dumping. Dumping sometimes can be beneficial to importing countries if the reason for selling products at lower prices is that foreign demand curve is more elastic and the firm just wants to price discriminate (Viner 1923). In practice, however, dumping is illegal in the United States and some other countries because it is regarded as a form of predatory pricing (Davis and McGuinness 1982; Ethier 1982) used by foreign firms to gain market share and market powers. The penalty is a high tariff or non-tariff barrier, or so-called anti-dumping duties. See also Article VI of the GATT.

environmentally harmful activities at less than the marginal cost of environmental degradations, i.e. a policy which does not internalise all environmental externalities'. (Rauscher 1994: 824).

'Eco-dumping' and its counterpart, anti-dumping, have emerged as a new issue threatening the trade liberalisation agenda of the Asia Pacific Economic Forum (APEC) and the World Trade Organisation (WTO). As the trade and environment debate intensified, there has been a resurgence of calls for a 'level playing field', 'harmonisation of environmental standards' or 'fair trade', and fears of loss of international competitiveness of environmentally sensitive industries from developed countries in the 1990s. Developing countries, on the other hand, see these calls as new protectionism, in the form of hidden non-tariff barriers, and are concerned about market access problems (Dua and Esty 1997).

An even more important issue facing developing countries concerns appropriate development strategies. Is there a conflict between environmental standards and international competitiveness? Do developing countries need to sacrifice their hopes for economic development, or international competitiveness more narrowly, in the interests of higher environmental standards?[2] Any degradation of environment due to lax environmental standards will have negative effects on the sustainability of economic development. The question then becomes clear. Is there a choice to be made between economic development (or narrowly, international competitiveness of ESG industries) versus environmental standards or should economic development take the environmental standards into account?

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[2] For an interesting analysis of global warming and developing countries, see Schelling (1992).

There have been several normative analyses of this issue in the literature. These include Bhagwati and Hudec 1996, Chichilnisky 1994, Brander and Taylor 1997, Anderson and Blackhurst 1992, Esty 1994, Dua and Esty 1997, Porter and van der Linde 1995, Markusen 1997 and Barrett 1994, among others (see also Chapter 2). What is lacking is further empirical analysis, as pointed out in a 1995 ministerial report to the OECD Council, 'the next stage of the OECD's work programme should include empirical analysis of selected policy areas and economic sectors' (OECD 1995).

In the context of this literature, this chapter examines trade liberalisation and environmental policy from an empirical perspective. It aims to investigate the effectiveness of 'eco-dumping', if any, on the international competitiveness of environmentally sensitive industries. I seek to examine whether the introduction of stringent environmental policies will lead to a decline in ESG industries in the presence of a technology factor. To this end, a generalised GDP function, which incorporates both technological change and increasing returns to scale, is set up and a flexible translog function form is used to approximate this generalised GDP function. Seemingly unrelated regression estimation (SURE) techniques are used to estimate a system of sectoral share equations derived from the generalised GDP function. Environmental stringency is treated as a factor of production, as discussed extensively in Chapter 4, together with capital, labour, land, mineral, oil and coal endowments. The technology level is regarded as an important determinant of the sectoral share in production. The basic hypothesis is that the environmental factor is not a significant determinant of the international competitiveness of environmentally sensitive industries, while technology is.

This chapter is organised as follows. The generalised GDP function is derived in the next section. A flexible translog function form is set up to approximate the generalised GDP function in section 3. Section 4 discusses data and measurement issues. Section 5 reports the econometric results and tests their robustness. The final section presents a conclusion.

Technology, increasing returns to scale and the generalised GDP function

Following Samuelson (1953), Dixit and Norman (1980), Woodland (1982), Kohli (1993) and Harrigan (1997), I consider a small open economy characterised by fixed aggregate factor supplies, constant returns to scale, and competitive market clearing. It can be shown that the equilibrium for the production sector can be obtained using the following maximisation problem[3]

$$\textbf{Max} \quad \mathbf{p} \bullet \mathbf{y} \quad \text{subject to } \mathbf{y} \in \mathbf{Y}(\mathbf{v}) \qquad (7.1)$$

$$\mathbf{p}, \mathbf{y} \in \mathbb{R}^{N}, \mathbf{v} \in \mathbb{R}^{M},$$

where **y** is the N-dimensional output vector, **p** is the price vector for output, **v** is the M-dimensional factor endowment vector, and **Y (v)** is the set of all output vectors which can be produced given the technology and the factor endowment. Its boundary is called the production possibility frontier. This is essentially the problem that a central planner would attempt to solve given the price vector **p** and the factor

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[3] Woodland (1982) shows that the maximum GDP function G (**p, v**) is essentially the same as the minimum factor payment function m (**p, v**). They are dual. The term GDP function is sometimes called the revenue function (Dixit and Norman 1980), or restricted profit function (Diewert 1974). The function actually estimated is invariably a measure of the income generated in the country at the prices facing producers, i.e., GDP at factor cost. It is not GDP at market prices which includes tariff revenue.

endowment vector **v**. The optimum **y** is clearly a function of **p** and **v**: $\mathbf{y}^* = \mathbf{f}(\mathbf{p}, \mathbf{v})$. Substituting this optimum output vector $\mathbf{y}^*$ into the objective function $\mathbf{p} \bullet \mathbf{y}$ gives the GDP function which is a function of **p** and **v** as well. The GDP function can be written as

$$G = G(\mathbf{p}, \mathbf{v}) \tag{7.2}$$

$G(\mathbf{p}, \mathbf{v})$ is non-decreasing, linearly homogenous, and concave in **v**, and non-decreasing, linearly homogenous, and convex in **p**.

This optimisation problem may also be illustrated diagrammatically in Figure 7.1 for the case of 2 × 2. In Figure 7.1, the area OAB is the production possibility set given the economy's factor endowment. The optimum output vector $\mathbf{y}^0$ can be solved given the price vector, **p**. This gives the point y^0 where the highest iso-GDP line is tangent to the production possibility curve given the factor endowment vector **v**. The price vector **p**, drawn starting from any point y^1 (not shown on the graph) on the iso-GDP line, must be orthogonal to any vector starting at y^1 and lying on the iso-GDP line. This is so because for any y^2 that itself lies on iso-GDP line, we have

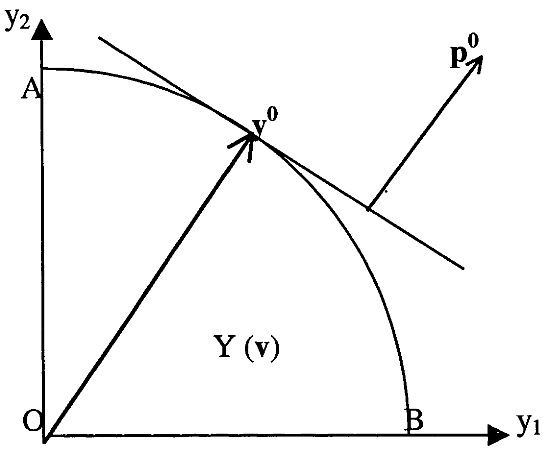
$$\mathbf{p}\,\mathbf{y}^1 = \mathbf{p}\,\mathbf{y}^2 = \text{GDP}.$$

Hence

$$\mathbf{p}\Delta\mathbf{y} = 0 \text{ for } \Delta\mathbf{y} = \mathbf{y}^2 - \mathbf{y}^1.$$

Thus, vector **p** is orthogonal to vector $\Delta\mathbf{y}$. Note that when we draw the price vector in the diagram, we use the 'units' on the axes to represent units of prices rather than goods.

Figure 7.1 Geometric illustration of maximisation of GDP function (1)



The GDP function approach has proved very useful in international trade theory analysis and trade empirical studies. As long as the GDP function is twice continuously differentiable, applying Hotelling's lemma gives the gradients (derivative) of G (**p, v**) with respect to **p** and **v** which are the vector of output supplies and vector of factor price, respectively.

$$\mathbf{y} = G_p(\mathbf{p}, \mathbf{v}) \quad \text{and} \quad \mathbf{w} = G_v(\mathbf{p}, \mathbf{v}) \tag{7.3}$$

Constant returns to scale and identical technological change are two of the basic assumptions underling the Heckscher–Ohlin theorem. It has been argued by 'new trade theory' that increasing returns to scale is one important factor that explains trade patterns, especially the large observed volume of intra-industry trade. We can demonstrate that the assumption of constant returns to scale can easily be relaxed in the generalised GDP function framework.

In the case of increasing returns to scale, a firm's output is not only a function of factorial value added $f(\mathbf{v})$, as in the case of constant returns to scale, but also a function of industry output $g(Y)$.

$$\mathbf{y} = g(Y)\, f(\mathbf{v}) \qquad (7.4)$$

where $g' > 0$ and $g'' < 0$, indicating that the larger the industry, the more efficient the firm will be. And $\mathbf{Y} = \sum\mathbf{y} = g(\mathbf{Y})\, f(\mathbf{v})$ is the industry output vector. Let the equilibrium industry output vector be $\underline{Y}$, then the firm will maximise $\{\mathbf{p}g(\underline{Y})\}\cdot f(\mathbf{v})$, where $g(\underline{Y})$ can be treated as a scalar of price vector $\mathbf{p}$. The GDP function then becomes

$$G = G(\mathbf{p}g(\underline{\mathbf{Y}}), \mathbf{v})$$

or

$$G = G(\theta\mathbf{p}, \mathbf{v}) \qquad (7.5)$$

where $\theta = \text{diag}\,(\theta_1, \theta_2, \ldots, \theta_N) = g\,(\underline{\mathbf{Y}})$.

Similarly, applying Hotelling's lemma gives the gradients (derivative) of $G(\mathbf{p}g(\underline{\mathbf{Y}}), \mathbf{v})$ with respect to $\mathbf{p}$ and $\mathbf{v}$, which are the vector of output supplies and vector of factor price, respectively.

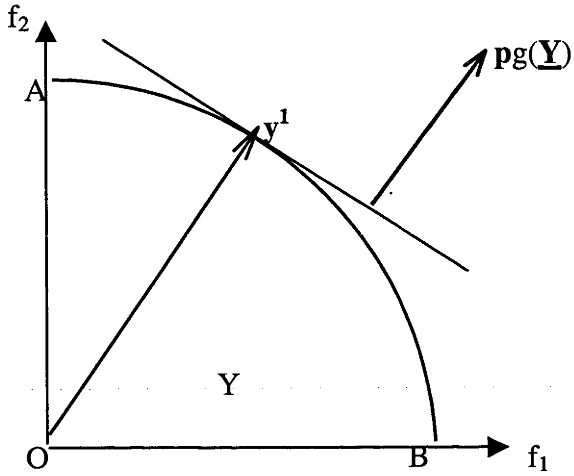
$$\partial\, G(\theta\mathbf{p}, \mathbf{v}) / \partial\mathbf{p} = \{\partial\, G(\theta\mathbf{p}, \mathbf{v}) / \partial(\theta\mathbf{p})\} \bullet \{\partial(\theta\mathbf{p}) / \partial\mathbf{p}\} = \theta f(\mathbf{v}) = \mathbf{y}$$

and

$$\partial\, G(\theta\mathbf{p}, \mathbf{v}) / \partial\mathbf{v} = \mathbf{w} \qquad (7.6)$$

where $\partial G(\theta\mathbf{p}, \mathbf{v}) / \partial(\theta\mathbf{p}) = f(\mathbf{v})$ and $\partial(\theta\mathbf{p}) / \partial p = g(\underline{\mathbf{Y}})$. This can be illustrated diagrammatically as in Figure 7.2. Comparing Figure 7.2 with Figure 7.1, we can see that increasing returns to scale can be modelled as industry-specific price changes, and the optimum output vector is again given by the gradient of the GDP function.

Figure 7.2 Geometric illustration of maximisation of GDP function (2)



Dixit and Norman (1980) and Harrigan (1997) arrived at a similar result by relaxing the assumption of no technology difference across countries and industries. Suppose there exists a production function for each good given by

$$\mathbf{y} = \varphi f(\mathbf{v}) \tag{7.7}$$

where φ is a scalar parameter relative to some base country. The assumption of the existence of distinct production functions implies that joint production is ruled out. The resulting GDP function can be shown to have the form

$$G = G(\varphi \mathbf{p}, \mathbf{v}) \qquad (7.8)$$

where $\varphi = \text{diag}\ \{\varphi_1, \varphi_2, \ldots, \varphi_N\}$. This formulation implies that industry-specific neutral technology change can be modelled in the same way as an industry-specific price increase, as in the case of increasing returns to scale.

However, it is now clear that the parameter attached to the price vector stands not only for the effect of industry-specific neutral technology change, as discussed by Harrigan (1997), but also for increasing returns to scale, which was not included in Harrigan's study.

Approximation of the generalised GDP function using flexible functional form

Having laid out the theoretical background, the next step towards testing the hypothesis is to approximate the GDP function using a flexible functional form. Since its introduction by Christensen, Jorgenson and Lau in 1973, the translog function has received considerable attention in the empirical literature. It has several advantages over the Cobb–Douglas and CES functions. Following Woodland (1982), Kohli (1978; 1991 and 1993) and Harrigan (1997), a translog function is used to approximate the GDP function. The translog GDP function takes the form

$$\begin{aligned} \ln G(\theta \mathbf{p}, \mathbf{v}) = \ln \alpha_{00} &+ \sum_j \alpha_{0j} \ln \theta_j p_j + \sum_i \beta_{0i} \ln v_i \\ &+ 1/2 \sum_j \sum_k \alpha_{jk} \ln \theta_j p_j \ln \theta_k p_k \qquad (7.9) \\ &+ 1/2 \sum_i \sum_m \beta_{im} \ln v_i \ln v_m + \sum_j \sum_i \gamma_{ji} \ln \theta_j p_j \ln v_i \end{aligned}$$

where j and k stand for products that are in $\mathbb{R}^N$ while i and m denote factor supplies that are in $\mathbb{R}^M$, θ is a variable capturing the effects of both technology level and increasing returns to scale. We can impose symmetry by requiring that $\alpha_{jk} = \alpha_{kj}$ and $\beta_{im} = \beta_{mi}$ for all j, k, i and m. Since the GDP function is linear in **v** and **p**, we require

$$\sum_j \alpha_{0j} = 1 \qquad \sum_i \beta_{0i} = 1 \qquad \sum_j \alpha_{jk} = 0 \qquad \sum_i \beta_{im} = 0 \quad \text{and} \quad \sum_i \gamma_{ji} = 0$$

Differentiating ln G($\theta\mathbf{p}$, **v**) with respect to each ln p_j and imposing the homogeneity restrictions $\Sigma_j\ \alpha_{jk} = 0$ and $\Sigma_i\ \gamma_{ji} = 0$ and adjusting the terms gives the sectoral share in GDP, $S_j = p_j\ y_j / G$ as a function of technology parameters, prices and factor supplies:

$$S_j = \alpha_{0j} + \sum_{k=2}^{N} \alpha_{kj} \ln (p_k / p_1) + \sum_{k=2}^{N} \alpha_{kj} \ln (\theta_k / \theta_1) + \sum_{i=2}^{M} \gamma_{ij} \ln (v_i / v_1) \qquad (7.10)$$

$$j = 1, 2, \ldots, (N-1)$$

In the case of free trade, each country faces the same prices but they differ in their factor endowments, technology level and scale economy. This implies $\Sigma_k\ \alpha_{kj} \ln (p_k / p_1)$ is a constant and it can be factored into the constant term. Following Harrigan (1997), if one takes into account the fact that many goods are non-traded, only tradable goods price will be absorbed into the constant term. The problem is that data for non-tradable goods prices are generally not available. One approach is to treat them as random with some estimable probability distribution that may generate a stochastic process with a constant dummy for each country and a classic disturbance term. These reformulations are defined by α in (7.11). Therefore, we have the following estimated equation

$$S_j = \alpha + \sum_{k=1}^{N} \alpha_{kj} \ln(\theta_k) + \sum_{i=2}^{M} \gamma_{ij} \ln(v_i / v_1) + \varepsilon_j \qquad j = 1, 2, \ldots, (N-1) \tag{7.11}$$

The only sign restriction on this equation in theory is that the own-technology/returns to scale effect, α_{jj}, is positive: holding other factors constant, an increase in the technology level should lead to an increase in its sectoral share. Theory also requires that the cross-technology effects are symmetric, $\alpha_{kj} = \alpha_{jk}$ for all sectors j and k, $k \neq j$.

Since θ is a variable capturing the effects of both technology level and increasing returns to scale, we assume the following relationship between the effect of technology level θ_t, and increasing returns to scale θ_s

$$\theta = \theta_t^{\tau} \theta_s^{1-\tau} \tag{7.12}$$

Substituting equation (4.12) into (4.11) gives

$$S_j = \alpha + \sum_{k=1}^{N} \alpha_{kj} \tau \ln(\theta_{kt}) + \sum_{k=1}^{N} \alpha_{kj} (1-\tau) \ln(\theta_{ks}) + \sum_{i=2}^{M} \gamma_{ij} \ln(v_i / v_1) + \varepsilon_j \qquad j = 1, 2, \ldots, (N-1) \tag{7.13}$$

With data on technology level, increasing returns to scale and factor endowments, equation (7.13) can be estimated by substituting equation (7.12). However, data on increasing returns to scale across industries and/or countries are generally not available. The best way to approach this problem may be to treat the increasing returns to scale effect as random with some estimable probability distribution as ζ

$$\zeta_i = \rho_i + e_i \tag{7.14}$$

where e_i is white noise. Rewriting equation (7.13) using (7.14) gives the equation to be estimated

$$S_j = \beta + \sum_{k=1}^{N} \beta_{kj} \ln(\theta_{kt}) + \sum_{i=2}^{M} \gamma_{ij} \ln(v_i / v_1) + e_i \qquad j = 1, 2, \ldots, (N-1) \tag{7.15}$$

where constant term β, which equals to $(\alpha + \Sigma\alpha_{kj}\ (1-\tau)\ \ln(\theta_{ks}))$ with $k = 1$ to N, combines the effects of all goods prices, non-traded goods technology parameters and increasing returns to scale effect and $\beta_{kj} = \alpha_{kj}\tau$.

Data and measurement

To estimate the above model, I need data on sectoral output share, technology level and factor endowment. As to sectoral output share, I choose ISIC 33, 34, 35, 36 and 37, as follows. These five industries are generally regarded to be the environmentally sensitive industries. All data are for 1988.

Sectoral output share

Data on sectoral output value added and sectoral employment are available from the UNIDO (United Nations Industrial Development Organisation) industrial statistics database. GDP in current price data are from the World Bank CD-ROM *World Development Indicators 1997*. Sectoral output value added is divided by GDP to obtain the sectoral output share as the dependent variable.

Table 7.1 Industry classification codes for environmentally sensitive industries

	ISIC code	descriptions
1.	33	Manufacture of wood and wood products
2.	34	Manufacture of paper, paper products and printing
3.	35	Manufacture of chemicals and chemical products
4.	36	Manufacture of non-metal mineral products
5.	37	Manufacture of basic metal products

Source: UNIDO (1992).

Technology

Technology is a variable that has no uniform definition, especially in the empirical literature. Total factor productivity is sometimes used to measure Hicks-neutral technology differences across industries (and/or countries). Since data for sectoral factor supplies are not available, sectoral value added per worker is therefore used instead. This can be justified as follows. The first is the fact that embodied technology changes (especially labour augmenting changes) can be regarded as a reasonable approximation of the process of technology progress. As shown in Barro and Sala-i-Martin (1995: 34), the long-term experience of the United States and some developed countries 'suggests that a useful theory would predict that per capita growth rates approach constants in the long run; that is, the model would possess a steady state'. Therefore technological progress must take the Harrod-neutral (labour augmenting) form in order for the model to have a steady state. Second, if the production function takes the Cobb–Douglas form, it is possible for technological progress to be both Hicks-neutral and Harrod-neutral. Suppose the production function, in the case of two factors, Capital K_t and Labour L_t, is

$$Y_t = f(K_t, A(t)L_t) = \beta K_t^{\alpha} (A(t) L_t)^{1-\alpha} \tag{7.16}$$

After arranging items on the right-hand side, this function becomes

$$Y_t = (A(t))^{1-\alpha} \beta K_t^{\alpha} L_t^{1-\alpha} = \gamma K_t^{\alpha} L_t^{1-\alpha} \tag{7.17}$$

This function satisfies the criteria of both Hicks-neutrality and Harrod-neutrality.

Environmental factor

Data on the environmental factors is generally not available. In light of this, an aggregate index number is often chosen. For example, quoting data from Walter and Ugelow (1979), Tobey (1990) chose an index number to approximate a country's environmental stringency which is measured on a scale from one to seven for a set of 23 countries.

The latest attempt to 'measure the status of environmental policy and performance' is a World Bank project by Dasgupta *et al.* (1995). This dataset has been discussed in Chapter 5 and is also shown in Table 7.2. Since sectoral output value added and factor endowment data are not available for some of the countries included and therefore there is a lack of degrees of freedom in the econometric study, this dataset is not explicitly employed. However, I construct the environmental stringency variable on the basis of their data.

Table 7.2 Environmental stringency and GDP per capita for selected countries

Country	Environment Index	ICPGDP	PCGNP	Rank by Environment Index
Germany	951	16920	22320	1
Switzerland	945	21690	32680	2
Netherlands	900	14600	17320	3
Finland	894	15620	26040	4
Ireland	871	9130	9550	5
Bulgaria	737	7900	2250	6
Korea	686	7190	5400	7
Jamaica	633	3030	1500	8
Czech	622	3470	3470	9
S.Africa	619	5500	2530	10
Tunisia	589	3979	1440	11
Trinidad	563	8510	3610	12
China	530	1950	370	13
India	507	1150	350	14
Pakistan	506	1770	380	15
Brazil	492	4780	2680	16
Jordan	474	4530	1240	17
Ghana	465	1720	390	18
Kenya	464	1120	370	19
Thailand	448	4610	1420	20
Philippines	447	2320	730	21
Paraguay	443	3120	1110	22
Egypt	441	3100	600	23
Malawi	441	670	200	24
Zambia	437	810	420	25
Nigeria	396	1420	290	26
Mozambique	368	620	80	27
Bangladesh	363	1050	210	28
Tanzania	341	540	110	29
Papua NG	329	1500	860	30
Bhutan	256	510	190	31
Ethiopia	253	310	120	32

Note: PCGNP stands for per capita GNP and ICPGDP for per capita GDP estimates compiled by the UN International Comparisons Program. 'Environment Index' denotes the environmental stringency index compiled by Dasgupta *et al.*, World Bank.
Source: Dasgupta *et al.* (1995).

Table 7.2 shows the environmental stringency index developed by the World Bank project. One interesting feature of this dataset is that the relationship between per capita income and environmental stringency is positive and highly significant. As can be seen in Table 7.3, the Spearman correlation coefficients between the environmental stringency index, and ICPGDP and PCGNP is -0.86987 and -0.8553, respectively. Both are statistically significant at the 0.01 per cent level. This suggests that higher income countries tend to have more stringent environmental policies. Based on this result I use GDP per capita as an 'instrumental variable' to the environmental stringency index. Of course, the higher a country's GDP per capita, the more stringent its environmental policy.

Table 7.3 The Spearman correlation Test

	Rank	ICPGDP	PCGNP
ICPGDP	0.8678		
	(0.0001)		
PCGNP	0.8537	0.9554	
	(0.0001)	(0.0001)	
Environmental stringency	-0.9999	-0.8699	-0.8553
	(0.0001)	(0.0001)	(0.0001)

Note: numbers in parentheses are p-values. See also Table 7.2 for notations of variables.
Source: Author's calculations.

Other factor endowments

Although data on sectoral factor supplies are difficult to get for the countries of interest, national factor endowment data are used to measure the fixed effect of factor abundance. The national factor endowment can be interpreted as the mean of the sectoral factor input. The justification can easily be found in the literature on the production possibility frontier where provincial data is used as the mean of firm level data. Since the econometrically estimated model is a system equation, these factor endowment variables examine whether countries with higher endowments in one factor will tend to be associated with a higher sectoral share in one of the sectors.

These factor endowments are provided by Song (1996) and include: (1) Capital: capital stock at constant prices assuming 15-year average life of assets, in US$ million; (2) Labour force; (3) Labour 1: number of workers classified as professional or technical; (4) Labour 2: number of literate non-professional workers; (5) Labour 3: number of illiterate workers; (6) Land; (7) Oil: crude oil production plus production of natural gas, in thousands of US dollars; (8) Coal: production of primary solid fuels (coal, lignite, and brown coal) plus natural gas, in thousands of US dollars; (9) Minerals: composite of 12 kinds of major minerals. Note that the sum of Labour 1 to 3 is equal to the total labour force in each sector of each country.

Data summary

The country coverage in this dataset includes 16 out of the 18 APEC countries and most OECD countries. Table 7.4 gives a summary of how the 30 countries differ in their production. Each column gives the percentage share of manufacturing value added in total GDP. The last column gives the percentage share of the five environmentally sensitive industries' value added in total manufacturing value added. One of the interesting features is that environmentally sensitive industries account for 40 to 50 per cent of the total manufacturing value added for the majority of the countries. Other columns give the percentage share of each industry's value added in total manufacturing value added. We can see that countries vary largely as to the composition of their environmentally sensitive industries' production. The variability in these environmentally sensitive industries' output share across countries is the focus of the study in next section.

Table 7.4 Share of manufacturing in GDP and shares of selected industries in total manufacturing in 1988.

	Manufacturing	Wood Prod.	Paper & Printing	Chemicals	Non-Metal	Metal	ESGs
Australia	15.4	5.7	11.2	13.4	4.8	9.8	44.8
Canada	21.5	6.2	15.2	15.7	3.4	7.8	48.2
Chile	18.1	3.5	9.2	17.1	3.2	26.5	59.4
China	35.7	1.3	3.4	19.5	7.0	9.6	40.8
Denmark	20.7	4.7	10.0	15.4	5.2	1.5	36.8
Finland	28.9	7.0	24.3	10.6	4.5	5.2	51.7
France	21.7	3.0	7.4	19.6	4.3	5.6	39.9
Germany	32.1	2.5	4.2	20.9	3.5	5.4	36.6
Greece	25.8	2.3	5.3	16.8	8.0	8.1	40.6
Hong Kong	20.5	1.0	7.7	9.7	0.7	0.6	19.7
India	17.8	0.5	3.2	24.0	4.4	13.9	46.0
Indonesia	19.7	13.9	4.7	16.4	3.9	8.3	47.2
Italy	23.5	3.0	6.5	14.0	6.1	7.7	37.4
Japan	28.2	2.7	7.9	15.7	4.6	7.1	37.9
Korea, Rep.	32.1	1.5	4.5	17.5	4.3	7.2	35.1
Malaysia	21.2	6.9	4.2	26.5	6.1	3.4	47.1
Mexico	26.8	0.5	4.4	23.0	7.7	11.8	47.3
Netherlands	18.8	1.8	10.1	25.9	3.7	5.3	46.7
New Zealand	18.2	6.6	14.1	13.9	3.8	3.8	42.2
Norway	14.0	6.1	14.6	11.8	3.6	12.9	48.9
Philippines	25.6	3.9	4.0	22.8	3.8	6.2	40.7
Portugal	27.9	4.3	11.5	15.6	9.0	3.1	43.3
Singapore	29.9	1.4	5.4	20.7	1.2	1.2	30.0
Spain	24.1	4.0	7.1	17.9	6.7	6.4	42.1
Sri Lanka	15.4	1.2	4.1	9.9	6.1	0.9	22.0
Sweden	25.2	6.1	16.3	12.9	2.9	6.1	44.3
Taiwan	37.2	3.0	4.1	24.0	3.8	6.6	41.4
Thailand	25.8	2.8	18.2	17.0	6.3	2.6	46.9
Britain	25.2	3.3	10.7	17.7	5.4	5.0	42.0
United States	20.0	3.0	11.2	17.0	2.9	4.2	38.3

Notes: The column labelled 'Manufacturing' gives the percentage share of manufacturing value added in total GDP. The column labelled 'ESGs' gives the percentage share of the five environmentally sensitive industries' value added in total manufacturing value added. Other columns give the percentage share of each industry's value added in total manufacturing value added.
Source: Author's calculations.

Table 7.5 Summary statistics of the sectoral share for each industry across 30 countries

	Wood Prod.	Paper & Printing	Chemicals	Non-Metal	Metal
Mean	0.0074	0.0183	0.0373	0.0094	0.0142
Standard Deviation	0.0040	0.0116	0.0197	0.0045	0.0135
Sample Variance	0.0000	0.0001	0.0004	0.0000	0.0002
Minimum	0.0004	0.0025	0.0110	0.0014	0.0010
Maximum	0.0153	0.0532	0.0879	0.0228	0.0743

Note: Sectoral share refers to share of GDP (not in percentage terms).
Source: Author's calculations.

Table 7.6 Environmental stringency rank measured by GDP per capita

	GDPPC	Rank		GDPPC	Rank		GDPPC	Rank
Norway	21,615	1	Italy	13,949	11	Korea, Rep.	3,615	21
Japan	20,954	2	Australia	13,197	12	Malaysia	2,025	22
Denmark	20,158	3	Britain	12,663	13	Mexico	1,775	23
Sweden	19,559	4	New Zealand	11,050	14	Chile	1,742	24
United States	18,973	5	Hong Kong	9,461	15	Thailand	1,050	25
Finland	18,653	6	Singapore	8,656	16	Philippines	603	26
France	16,608	7	Spain	7,956	17	Indonesia	468	27
Canada	16,010	8	Taiwan	5,507	18	Sri Lanka	414	28
Netherlands	15,129	9	Greece	4,829	19	India	346	29
Germany	14,699	10	Portugal	4,438	20	China	272	30

Note: GDPPC stands for GDP per capita in 1988 (constant prices, US$, 1987). The ranking is calculated on the basis of GDPPC.
Source: Author's calculations.

The summary statistics for the dependent variables for each industry are given in Table 7.5. Environmental stringency is calculated as an index on the basis of a country's level of development measured by GDP per capita in constant 1987 US dollars. For these 30 countries under study, the index number runs from 1 (strict) to 30 (tolerant). The lower the index number, the more stringent the country's environmental policy.

Empirical results

Seemingly unrelated regression estimation (SURE) techniques are used to estimate equation (7.15) as a system. The estimation result and hypothesis tests are reported in Table 7.7. Standardised coefficients are reported in Table 7.9. For each equation, the dependent variable is the sectoral share in GDP in each country. The definitions of independent variables in this system equation are given in Table 7.8. Since the sectoral shares for each country will sum to one rather than one hundred, and the independent variables are all in logarithms, the interpretation of the coefficient carries the form of semi-elasticity. A parameter of 0.0013 indicates that a 10 per cent increase in the independent variable will raise the output share by 0.013 percentage points. Constant terms that absorbed the country fixed effect, scale effect, all goods prices effect and non-tradable goods technology effect are included in the regression but not reported in this table.

As shown in Table 7.7, the own-technology effects are all positive, as suggested by theory, and statistically significant at the 5 per cent level in most cases. The largest positive effects are in chemicals and paper and printing, with slope coefficients of 0.0146 and 0.0140, respectively. This means that a 10 per cent technology improvement in the chemicals sector will lead to a 0.146 percentage point increase in its sectoral share of GDP and a 0.140 percentage point increase in the paper and printing sector. Technological improvement in the non-metal products sector has a small positive effect, but is only statistically significant at the 13.96 per cent level. The wood products sector shows a positive technological effect, but it is not statistically significant.

The cross-technology effects are, however, mixed as suggested by theory. In most cases, the cross-technology effects are small and statistically insignificant except the cross-technology effects between the metal and non-metal sectors where they are negative and statistically significant. This result is similar to that in Harrigian's study (1997) using the OECD International Sectoral Data Base (ISDB), although he uses total factor productivity as an instrument of technology.

Turning now to the effects of the environmental factor on sectoral shares, it appears that environmental stringency has only a negligible effect and is shown to be not statistically significant in all sectors. This suggests that countries with less stringent environmental policy are not necessarily those with a higher sectoral share of ESGs. This finding confirms the time-series evidence, as suggested in Chapters 3 and 4.

Other resource endowment factors do have statistically significant effects on sectoral shares of GDP. The factor endowment effects underlying the new framework are essentially similar to that of Leamer (1984) and Song (1995) using the Heckscher–Ohlin–Vanek framework. Our findings include the following: a 10 per cent increase in the endowment of mineral resource is associated with 0.01 per centage increase in the non-metal sectoral share of GDP; countries with a relatively large endowment in

Table 7.7 SURE estimates of the GDP share equations

Variable	Wood Prod.	Paper & Printing	Chemicals	Non-Metal	Metal
LNT1	0.0013	0.0007	-0.0017	-0.0010	0.0019
	(0.3786)	(0.2867)	(-0.6919)	(-0.4752)	(1.1916)
LNT2	0.0007	0.0140	-0.0041	0.0021	0.0001
	(0.2867)	**(4.1391)**	(-1.2265)	(1.1167)	(0.0600)
LNT3	-0.0017	-0.0041	0.0146	-0.0035	-0.0009
	(-0.6919)	(-1.2265)	**(2.6070)**	(-1.7179)	(-0.2885)
LNT4	-0.0010	0.0021	-0.0035	0.0042	-0.0039
	(-0.4752)	(1.1167)	(-1.7179)	**(1.4858)**	(-3.2779)
LNT5	0.0019	0.0001	-0.0009	-0.0039	0.0120
	(1.1916)	(0.0600)	(-0.2885)	(-3.2779)	**(3.1795)**
LNQ	0.0003	-0.0015	0.0023	0.0002	0.0008
	(0.5098)	(-1.3582)	(1.1105)	(0.4058)	(0.4644)
LNLD	0.0007	0.0038	-0.0112	-0.0030	-0.0025
	(0.7061)	**(2.1368)**	**(-3.2160)**	**(-3.2098)**	(-0.9479)
LNLB	-0.0016	0.0045	0.0052	0.0003	0.0060
	(-0.5823)	(1.3165)	(0.8368)	(0.1159)	(1.3184)
LNMI	0.0000	-0.0011	0.0016	0.0010	0.0009
	(0.12826)	(-1.5911)	(1.2273)	**(2.8046)**	(0.9389)
LNOI	-0.0001	-0.0005	0.0003	-0.0001	0.0000
	(-0.6518)	**(-2.9725)**	(0.8183)	(-0.5993)	(-0.1702)
LNCO	0.0001	0.0000	0.0011	0.0002	0.0004
	(0.4227)	(0.0563)	**(2.6937)**	**(2.2264)**	(1.1547)
LNK	0.0005	-0.0053	0.0007	0.0013	-0.0055
	(0.1067)	(-0.7237)	(0.0498)	(0.3011)	(-0.5303)
Hypothesis Tests (p-value)					
Homogeneity	0.860	0.130	0.912	0.582	0.217
Significance tests					
A1: Technology	0.0755	0.00002	0.0135	0.0072	0.00005
A2: Factor endowments	0.6400	0.055	0.0019	0.0017	0.137
A3: Technology & Factor endowments.	0.112	0.0000	0.00005	0.00003	0.00006

Notes: SURE estimation results are listed in each column, with t-statistics in parentheses. For a detailed definition of variables, see Table 4.8. Marginal significance levels of hypothesis tests are reported below the heading 'Hypothesis Tests' above. These are computed using the appropriate Wald statistic with Chi-square distribution. The hypothesis for the homogeneity test is that the sum of the factor endowment terms is zero. It is tested for each industry separately with χ^2 (1). The hypothesis for A1 to A3 is that the indicated coefficients are all zero. The test statistics for A1 to A3 are χ^2 (5), χ^2 (6), χ^2 (11), respectively.

Source: Author's calculations.

Table 7.8 Definition of the variables

(1) LNT1 to LN T5: Log of the technology level for each industry starting from wood products in the first row in Table 7.6.

(2) LNQ: log of the environmental stringency index. Number 1 stands for the most stringent environmental policy while number 30 stands for the least stringent.

(3) LNLD: log of the land area.

(4) LNLB: log of the total labour force.

(5) LNOI: log of the oil factor endowment as defined in the text.

(6) LNMI: log of the mineral factor endowment as defined in the text.

(7) LNCO: log of the coal factor endowment as defined in the text.

(8) LNK: log of the capital stock as defined in the text.

Table 7.9 Estimates of GDP share equation: standardised coefficients

Variable	Wood Prod.	Paper & Printing	Chemicals	Non-Metal	Metal
LNT1	**0.3641**	0.0651	-0.0927	-0.2496	0.1518
LNT2	0.1768	**1.2666**	-0.2163	0.4785	0.0106
LNT3	-0.4122	-0.3541	**0.7489**	-0.7747	-0.0710
LNT4	-0.2767	0.1953	-0.1931	**1.0036**	-0.3125
LNT5	0.4355	0.0112	-0.0458	-0.8090	**0.8415**
LNQ	0.1581	-0.2424	0.2246	0.0983	0.1065
LNLD	0.3949	0.7400	-1.2851	-1.4779	-0.4210
LNLB	-0.4858	0.4750	0.3210	0.0697	0.5424
LNMI	0.0751	-0.5597	0.4980	1.3391	0.4199
LNOI	-0.1491	-0.4247	0.1336	-0.1130	-0.0312
LNCO	0.1087	0.0092	0.5052	0.4759	0.2436
LNK	0.0007	-0.0034	0.0005	0.0012	-0.0042

Notes: The standardised coefficients are often known as 'beta' coefficients. They adjust the estimated coefficients by the ratio of the standard deviation of the independent variable to the standard deviation of the dependent variable. This makes it possible compare the size of the effects of each independent variable directly.

Source: Author's calculations.

coal are generally associated with high sectoral shares of chemicals and non-metals; countries with a larger endowment of oil are associated with a lower sectoral share of paper and printing; countries with a large amount of land (which includes forest land) endowment are associated with a higher share of paper and printing industries. A country's total labour force is not found to be significantly associated with high share of any one of the ESG sectors. The effects of capital endowment turn out to be insignificant in all cases. This might reflect the fact that capital is more mobile internationally than other natural resource endowment factors.

To understand the size of the effect of environmental stringency compared with the other factors, especially the technology factor, Table 7.9 shows the standardised coefficients of the SURE. The standardised coefficients are often known as 'beta' coefficients. They adjust the estimated coefficients by the ratio of the standard deviation of the independent variable to the standard deviation of the dependent variable. This makes it possible to compare the size of the effects of each independent variable directly. A standardised coefficient of 1.27 indicates that a one standard deviation increase in the independent variable will lead to an increase of dependent variable by 1.27 standard deviation. More interestingly, a normalisation of standardised coefficients provides more intuitive insight as in Table 7.10, using a standardised coefficient of the technology variable in each column as the basis for carrying out this normalisation. Comparing the size of the effect of environmental stringency with that of technology, we can see that the average effect of environmental stringency on sectoral share is only 0.23 times the effect of the technology factor.

Table 7.10 SURE estimates of GDP share equation: a normalisation of standardised coefficients

Variable	Wood Prod.	Paper & Printing	Chemicals	Non-Metal	Metal
LNT1	**1.0**	0.1	-0.1	-0.2	0.2
LNT2	0.5	**1.0**	-0.3	0.5	0.0
LNT3	-1.1	-0.3	**1.0**	-0.8	-0.1
LNT4	-0.8	0.2	-0.3	**1.0**	-0.4
LNT5	1.2	0.0	-0.1	-0.8	**1.0**
LNQ	**0.4**	**-0.2**	**0.3**	**0.1**	**0.1**
LNLD	1.1	0.6	-1.7	-1.5	-0.5
LNLB	-1.3	0.4	0.4	0.1	0.6
LNMI	0.2	-0.4	0.7	1.3	0.5
LNOI	-0.4	-0.3	0.2	-0.1	0.0
LNCO	0.3	0.0	0.7	0.5	0.3
LNK	0.0	0.0	0.0	0.0	0.0

Note: Normalisation is carried out on the basis of Table 4.9. See also text.
Source: Author's calculations.

Hypothesis tests are shown in Table 7.7. The Wald statistics are computed for each hypothesis and the marginal significance levels are reported. The homogeneity restrictions are not rejected for all the five cases. The technology factor and factor endowment are jointly significant (A3) at the 1 per cent level except in the case of the Wood sector where the significant level is 11.2 per cent. The technology factor and factor endowment are then tested separately (A1 and A2) and they are all significant at the 5 per cent level except that of the wood sector.

Conclusion

There are growing concerns in developing countries about the loss of international competitiveness and the impediments to economic development due to environmental regulation. Developed countries' concern about eco-dumping by developing countries with lax environmental policies has also become an important issue. This chapter has attempted to investigate, econometrically the effectiveness of 'eco-dumping', if any, on the international competitiveness of environmentally sensitive industries.

A generalised GDP function, which incorporated both technology change and increasing returns to scale, was set up and a flexible translog function form was used to approximate this generalised GDP function. Seemingly unrelated regression estimation (SURE) techniques were used to estimate a system of sectoral share equations derived from the generalised GDP function. Environmental stringency is treated as a factor of production together with capital, land, labour, mineral, oil and coal endowments. The technology level is regarded as an important determinant of the sectoral share in production. The basic hypothesis is that the environmental factor is not a significant determinant of the international competitiveness of environmentally sensitive industries while technology is.

The econometric results suggest that the own-technology effects are all positive, as suggested by theory, and statistically significant at the 5 per cent level in most cases. However, the environmental stringency variable has only a negligible effect and is shown to be not statistically significant in all sectors. This suggests that countries with less stringent environmental policies do not necessarily have higher sectoral shares of ESGs. While trade is not explicitly addressed, the implication for trade is immediate: to the extent that countries have similar tastes, the inferences about the determinants of production patterns found here will translate into inferences about a country's trade patterns (Harrigan 1997). This finding confirms the time-series evidence as suggested in Chapters 3 and 4, and supports the theoretical discussion in Chapter 6.

The policy implications are clear. On the one hand, these findings suggest that development strategies which rely on lax environmental regulations to achieve the economic goals of developing countries may not be appropriate since technological innovation may be a more relevant determinant of international trade competitiveness. There can be compromise between environmental standards and international competitiveness. Development strategies can take environmental standards into account.

On the other hand, the fear of eco-dumping from developing countries in the developed world seems ill-founded in light of these tests. The call for harmonisation of national environmental standards may not be justified, even from an empirical perspective.

8 International Trade and Environmental Regulation: Some Conclusions

This study set out to examine one of the most important issues relating to trade and the environment, namely, the effects of domestic environmental policy on international trade competitiveness. The central question addressed was whether stringent domestic environmental policies reduce the international competitiveness of environmentally sensitive industries.

Summary and major findings

This study is distinguished by two major innovations beyond the established literature: the examination of time-series evidence to explore the relationship between environmental regulations and trade patterns, and the introduction of technology factors, together with endowment factors, to explain the empirical evidence.

There are five steps in the development of the argument. I first provide time-series evidence on the effects of environmental policy on trade patterns, using the trade-in-goods approach. This is to investigate whether the patterns of exports of environmentally sensitive goods (ESGs) underwent systematic changes due to the introduction of stringent environmental standards in most developed countries in the 1970s and 1980s. More specifically, I seek to explore whether countries that introduced more stringent environmental regulations in the 1970s and 1980s lost their competitiveness in environmentally sensitive industries. For this purpose, a comprehensive dataset of trade flows of ESGs disaggregated to the four-digit level of the Standard International Trade Classification (SITC) was compiled. This data set covers 31 years and 34 countries, accounting for nearly 80 per cent of world exports of ESGs in 1995.

This dataset is then analysed from two perspectives: (1) the export performance of ESGs in the initial period (1965) and the end period (1995) is compared; (2) the export performance of ESGs in the intervening years is examined. To investigate the export performance of ESGs between the initial period and the end period, I calculate the percentage change in export performance of normalised trade flows of ESGs matrix for each country. Surprisingly, I find that the export performance of ESGs for most countries remained unchanged between 1965 and 1995. A more rigorous statistical test of the association between the revealed comparative advantage in ESGs in 1965 and 1995 also reveals a strong association. To examine the export performance in ESGs in the intervening years, I calculate a normalised trade-share weighted export revealed comparative advantage index for each country in each year. The time-series patterns of this indicator for those countries that have higher environmental standards do not deteriorate in a systematic way. These results are rather robust when subjected to various sensitivity tests. To summarise, time-series evidence from the trade-in-goods approach suggests that the export pattern for ESGs did not undergo systematic change, despite the introduction of stringent environmental standards in most developed countries in the 1970s and 1980s.

Secondly, I provide time-series evidence on the trade effects of environmental policy using a different approach, namely a factor-content-of-trade approach. The environment in this approach is regarded as a factor of production. The concept of trade in embodied environmental factor services captures the idea that traded goods embody an environmental factor service. If countries have different domestic environmental policies, the ability to pollute or the abundance of environmental services might differ. If the trade effects of domestic environment policy are significant, one would expect countries with stringent environmental regulations to have more embodied environmental factor services in their imports than their exports at each point in time, and that there would be systematic change in the pattern of embodied environmental factor services over time. The factor-content-of-trade approach is, therefore, a useful alternative to the trade-in-goods approach. In this approach, instead of using trade value to calculate net exports of environmental factor services, an approach taken in the literature, I use the trade-share-weighted average to impute the net export content of environmental factor services. I demonstrate that this modification removes possible biases from the effects of both inflation and macroeconomic imbalance. The result indicates that the net export content of environmental factor services for the majority of the countries in the study does not experience systematic structural change in the last 26 years, despite the introduction of stringent environmental regulations in most of the developed countries in the 1970s and 1980s. This observation is generally consistent with what I found using the trade-in-goods approach.

Thirdly, the observed time-series pattern is put into a multi-country econometric test using an extended gravity-equation framework. In this framework, bilateral exports depend on the countries' size and wealth, degree of inward-orientation, geographic distance that measures the natural obstacles to trade between trading partners and 'artificial' obstacles such as tariffs and environmental stringency. The extent of environmental stringency is measured by unique indices developed by the World Bank recently.

We test the following two hypotheses. The first is more stringent environmental regulations lower total exports, and/or exports of ESGs, and/or exports of non-resource-based ESGs. The second is that new trade barriers emerge to offset the effects of more stringent environmental regulations.

Our findings reject both hypotheses. Overall, higher stringency of environmental regulations does not reduce total exports, exports of ESGs or exports of non-resource-based ESGs. We found no evidence to support the hypothesis that new trade barriers emerge to offset the effects of more stringent environmental regulations. Furthermore, higher import tariffs in trading partners are found to reduce significantly reporter countrys' export performance in total exports, ESGs and non-resource-based ESG exports. These results support the empirical time-series observations using both the trade-in-goods-approach and the factor-content-of-trade approach, and appear to reflect the extent to which increases in the stringency of environmental regulations are accompanied by technological innovation which prevents the export performance of ESGs from deteriorating.

To explore the dynamic linkage between environmental regulation, technological innovation and growth, I set up an intertemporal dynamic general equilibrium model in which the more fundamental, dynamic determinant of a country's long-run growth is its capacity for technological innovation. The physical setup of this model is basically along the lines of recent endogenous growth literature, especially Uzawa (1965), Lucas (1988) and Rebelo (1991). Three key features characterise the model. First, it is based on the intertemporal optimisation of representative agents in the economy. Second, ESGs are modelled as an intermediate good, which is used in the production of final consumption goods. Third, R&D takes place by means of a linear technology and is sector specific (to the intermediate goods sector). Firms with an R&D sector therefore have to make decisions about the allocation of the dynamic factor that can be accumulated. With the production function exhibiting constant returns to scale in the factor that is accumulated, equilibrium is characterised by endogenous growth.

Two important issues can be addressed using this framework. First, what are the effects of environmental regulation on long-run growth? Second, how important is technological innovation in determining the long-run growth? The basic findings are that (1) changes in the stringency of environmental regulations do not have long-run growth effects; and (2) technological innovation is an important determinant of a country's long-run growth.

Fifthly and finally, I investigate the significance of the technology factor, as proposed both in the empirical study and the theoretical model above, in determining the international competitiveness of environmentally sensitive industries. For this purpose, a generalised GDP function, which incorporates both technology change and increasing returns to scale, is set up and a flexible translog function form is used to approximate this generalised GDP function. Seemingly unrelated regression estimation (SURE) techniques are used to estimate a system of sectoral share equations derived from the generalised GDP function. Environmental stringency is treated as a factor of production together with capital, labour, land, mineral, oil and coal endowments. The technology level is regarded as an important determinant of the sectoral share in production. The basic hypothesis is that environmental factor is not a significant determinant of international competitiveness of environmentally sensitive industries while technology is.

The econometric result suggests that the own-technology effects are all positive, as suggested by theory, and statistically significant at the 5 per cent level in most cases. However, the environmental stringency variable has only a negligible effect and is shown to be statistically insignificant in all sectors. This suggests that countries with less stringent environmental policy do not necessarily have higher sectoral shares of ESGs. While trade is not explicitly addressed, the implication for trade is straightforward: to the extent that countries have similar tastes, the inferences about the determinants of production pattern found here will translate into inferences about a country's trade pattern (Harrigan 1997).

The idea conveyed through this piece of work is simple. The trade effects of domestic environmental policy can be better understood if one allows for the dynamic Ricardian technology factor in the conventional Heckscher–Ohlin framework. Innovation and subsequent increases in relative labour productivity, together with factor endowments, are important factors in determining the relationship between environmental regulation and international competitivenes.

Policy implications

Two policy implications follow from this study. The first relates to development strategy for developing countries as to growth, trade and environment. The second relates to the effectiveness of eco-dumping.

Many developing countries have long seen environmental regulations and economic development as mutually exclusive. According to this view, to achieve rapid economic development and secure international competitiveness in environmentally sensitive industries, domestic environmental standards should not be stringent. To the extent that the environment has assumed a growing importance, this can be postponed until a high income level has been achieved. This perception has received considerable support from static cost–benefit analysis.

However, this idea is challenged by this study. This study has provided empirical time-series evidence across most of the countries involved in trade in ESGs. In general, I find that stringent environmental regulations did not reduce the international competitiveness of ESGs in the last three decades. The reason that higher domestic environmental regulations do not reduce competitiveness of ESGs is that environmental regulations appear to be productivity enhancing. Technological innovation is important in determining a country's long-run growth.

In the light of this finding, I argue that environmental regulations and international competitiveness should not be treated as mutually exclusive. A development strategy that relies on lax environmental regulations to achieve the economic goals of developing countries may not be appropriate since technological innovation appears to be more relevant to trade competitiveness. There can be a compromise between environmental standards and international competitiveness. Development strategies for developing countries, therefore, can accommodate environmental standards. Economic development does not require lax environmental standards.

Another closely related policy issue relates to the so-called 'eco-dumping' and 'anti-dumping'. This study suggests that less stringent environmental regulations do not increase the international competitiveness of ESGs. Hence, 'eco-dumping' appears to be ineffective in the light of the test. Debate on this issue should focus more on the facilitation of trade rather than restrictions on trade.

Directions for future research

The study provides a general but comprehensive picture of the effects on trade of domestic environmental policy. It suggests a number of useful directions for future research.

First, this study was constrained by the availability of the environmental stringency indices. The latest attempt by the World Bank has developed an index for 31 countries on the basis of the UNCED national reports. This is a rather small sample, however. Furthermore, to what extent this aggregate index reflects the degree of environmental stringency, especially the degree of actual enforcement, remains to be explored. Eliste and Fredriksson (1998) have followed this line using the same methodology but focused only on agriculture. Construction of comparable time-series environmental stringency indices is important to future work.

Secondly, industry and country level studies are required if one is interested in assessing the difference of the effects of environmental regulation on individual industries and countries. Certainly, the methodology developed in this study, especially in Chapters 3 and 4, can be readily applied to this question. The sensitivity of different industries to changes in environmental regulation could also be traced in future.

Thirdly, the result that tighter environmental regulations appear to generate greater trade, as demonstrated in Chapter 5, is worthy of fuller investigation. The results from Chapter 5 rely heavily on the World Bank environmental stringency index. Further investigation may involve looking for sectoral environmental stringency and trade policy variables which are more focused on ESGs.

Fourthly, a more realistic theoretical model of the dynamic relationship between environmental regulations and competitiveness needs to be further developed. This could also be the focus of future study.

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