ESSAYS IN ENVIRONMENTAL REGULATION AND INTERNATIONAL TRADE

by

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ABSTRACT: This thesis is composed of three essays. In the first essay I identify the effects of imposing a broad range of environmental regulations under different market conditions.. I compare four types of regulatory controls under Perfect Competition, Monopoly, and Cournot Competition: Emission Standards, Design Standards, Concentration Standards, and Output Standards. I rank each of the standards in terms of firm profitability, industry output, abatement costs, and social welfare. I derive sufficient conditions for Design, or Concentration Standards, to dominate Emission Standards. I show how the different forms of regulation can raise industry profits by reducing the degree of inter-firm competition. Further, I show how environmental regulations can enhance competition and yield a "double dividend": higher Social Surplus and less pollution.

In the second essay I extend the comparison of standards to an open country. I show how a country's choice of regulatory *regime* influences the *level* of environmental protection when governments care about the competitiveness of their industries. I show that the mode of regulation can create a "race to the bottom" if regulators behave strategically. I show that Emission Standards permit the race, as do Emission Charges. Design Standards, on the other hand, avoid the race altogether by breaking the link between environmental stringency and industrial competitiveness. Countries using Design Standards will always regulate emissions. This holds regardless of the environmental stance taken by competitor nations. If countries do not behave strategically, then Emission Standards and Emission Charges always dominate Design Standards.

In the third essay I use the concept of home biases in traded goods, or "Border Effects", to rank industries and countries in terms of their openness to trade. I first confirm the presence border effects for individual sectors and individual industries among OECD countries for 1970 to 1985. I also examine whether country-specific border effects are determined by the sectoral composition of a country's production. I find limited evidence to support this. Rather, per capita incomes appear to be the most important factor. The conclusion I draw is that the level of development appears to be the prime factor in explaining the differences in country-specific border effects. What countries produce is of some importance. Therefore, we should see continued, though possibly slow, reductions in home biases as all countries continue to develop. This will partially determine the kind of environmental regulation used as well as their level.

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CHAPTER 1: INTRODUCTION

Environmental regulators are given authority by their governments to restrict the actions of firms and individuals so as to improve environmental quality. They have access to a menu of diverse instruments in which to attain their environmental objectives. These instruments can be separated into incentive-based regulations and traditional Command and Control regulations. Incentive based regulations consist of emission charges, abatement subsidies, deposit-refund systems, and tradable emission permits. Command and Control regulations include quantitative restrictions on emissions, on the type and quantity of abatement, and on the input and output choices that firms can make.

Often, many types of regulation are each capable of achieving the environmental target sought. Each instrument forces firms to undertake a different set of activities so as to comply with regulations. This imposes different costs on firms and therefore on society. Furthermore, the selection of the environmental objective itself becomes a function of the choice of instrument. The regulator's preferred instrument must take into account the costs of imposing regulations in addition to the benefits to the environment. The regulator's choice can be difficult.

The prime difficulty in choosing instruments, and targets, is to correctly anticipate the actions of firms as they respond to regulation. This in turn depends on firms' private objectives as well as the way that firms interact with one another. For firms, the problem is to ensure that regulations yield the highest profits either by minimizing compliance costs or minimizing rival competition.

So far, regulations have primarily been of the Command and Control sort. Helfand (1991) and Potier (1997) claim that Command and Control dominate the regulatory arsenal and are likely to continue to do so. Dewees (1983) concurs and argues that concentration standards are the most realistic representation of present policies (p. 55). Despite this dominance, the use of Command and Control has not been fully explored in the theoretical literature. We do not yet have a clear idea how the broad range of controls alter the competitive forces in an industry. We do not know what *sort* of control is preferred. We do not know how firms' preferences vary across these instruments or whether they are equally averse to all forms of regulation. Although we know that incentive-based regulations dominate some forms of Command and Control, we do not know if they dominate all forms of control. A careful examination has not taken place.

The purpose of this thesis is to identify how the different Command and Control structures affect market outcomes, how they compare to one another, how they compare to incentive based regulations, and how the choice of instrument affects the environmental target chosen. I do this with three separate essays.

In the first essay (Chapter 2) I consider instrument choice in a closed economy. I compare four types of regulatory controls under Perfect Competition, Monopoly, and Cournot Competition: *Emission Standards* that limit firms' total allowable emissions, *Design Standards* that specify the type and quantity of firms' abatement expenditures, *Concentration Standards* that limit emissions per unit of output, and *Output Standards* that limit firms' production. I show how each affects market equilibrium under the different market scenarios. I identify the effects on firms' output and profits and the resulting social welfare. I also identify how the choice of instrument, interacting with the degree of competition, partially determines the optimal emission target itself.

I rank each of the standards in terms of firm profitability, industry output, abatement costs, and social welfare. I compare outcomes derived under both arbitrary and optimal emission targets. I show how targets and welfare differ across regulations since each tends to reduce competition by reducing firms' ability to respond to their competitors. Design and Concentration Standards have the smallest effect and so can become an efficient form of regulation. Emission Standards are the efficient mode of regulation in perfectly competitive markets. As market power increases, however, they become less desirable. I derive sufficient conditions for Design, and Concentration Standards, to dominate Emission Standards.

Firms have distinct preferences over regulation since the form of regulation alters their profitability. I show how profits can rise above the unregulated case under Emission and Output Standards. Profits fall under Design and Concentration Standards as well as with emission taxes.

On the other hand, I also show how environmental regulations enhance competition. This can occur when abatement expenditures reduce production costs, as would happen if effluent could be marketed. The implication is that regulations can yield a "double dividend": higher Social Surplus and less pollution. This double dividend has not been established in this context before. I show that a necessary, though not sufficient, condition is the presence of imperfectly competitive markets. It is not possible to generate the double dividend in perfectly competitive markets. The likelihood is also contingent on the form of regulation with Designs Standards most conducive to improved Social Surplus.

The underlying mechanisms and intuition are presented in a graphical form that incorporates the tradeoff between output effects and environmental quality in a simple way. This kind of systematic analysis between regulatory control and market structure has not been previously made.

In the second essay (Chapter 3) I turn to a discussion of an open economy. I consider how a country's choice of regulatory *regime* influences the *level* of environmental protection when governments care about the competitiveness of their industries in international markets. This comparison has not been made before. I compare Design Standards to Emission Standards and to Emission Charges. I show that the mode of regulation can create conditions where regulators weaken environmental targets to such an extent that firms become effectively unregulated. This "race to the bottom" only occurs if regulators behave strategically. The issue is that regulations create a link between a country's environmental stringency and its industrial competitiveness. This link is established under Emission Standards and reinforced under Emission Charges. Design Standards, on the other hand, avoid the race altogether by breaking the link between stringency and competitiveness. In effect, Design Standards commit a regulator to a policy of non-strategic intervention and so, under some circumstances, generates better outcomes. This is a new result. It is significant since Emission Standards and Emission Charges always dominate Design Standards if countries do not behave strategically. These results cast some doubt on whether incentive-based instruments are capable of diminishing the conflict between environmental stringency and international competitiveness.

I show further that countries that use Design Standards will always regulate emissions and never suffer a race to the bottom. This result holds regardless of the environmental stance taken by competitor nations. Hence, whenever a race might arise, governments always have an instrument that offers some degree of environmental protection.

I use a Three-Stage Game in which the choice of instruments comes before the choice of targets. This is relevant to federations like Canada where environmental targets are set at the provincial level rather than the federal and to the EU where the principle of subsidiarity requires that decisions take place at the regional, rather than at the community, level whenever possible. The analysis also suggests a possible role for harmonization of regulatory instruments without requiring countries to harmonize emissions targets. This allows countries to implement targets unilaterally while removing one potential conflict between nations.

These first two essays show that the problem facing regulators is quite different depending on whether the firms they regulate face competition from potentially unregulated foreign firms. The question then becomes which of the two extremes best exemplifies the conditions facing the domestic industry. Is the industry mostly closed or mostly open to trade? Is the country itself mostly closed or open to trade? How one answers this will partially determine the best way to regulate one's industries and to what extent.

In the third essay (Chapter 4) I try to gauge this by identifying the degree to which industries or countries may be considered open to trade. I do this by utilizing recent research that has identified a surprisingly large home bias in traded goods. International trade data shows that *intra-national* trade is much denser than *inter-national* trade even after accounting for the geographic distance and economic sizes of trading partners. This home bias in trade has been coined a "border effect" in the sense that trading across national borders seems to impose additional transactions costs on firms. This reduces the density of trade between nations and increases trade within nations. The greater the border effect, the more production is destined for domestic markets rather than for international markets. Measures of border effects then give us an indication of how important trade is to a country or to an industry.

I first confirm the presence of these border effects for individual OECD countries for the period 1970 to 1985. I use a new data set that has not been previously exploited for this purpose. Importantly, the data allows a careful disaggregation of manufacturing data into separate industries and sectors. This allows identification of sector-specific and industry-specific border effects for the entire sixteen-year period. I show that there is a high variance in both country-specific border effects and industry-specific effects. Border effects declined significantly across all countries and in virtually all industries. This suggests that competitive pressures may become more important in environmental design both at the aggregate level as well as at the industry level.

One question that arises in analyzing home biases is to what extent country-specific border effects are determined by the sectoral composition of national production. Countries specialize for many different reasons and so may end up concentrated in relatively open sectors. This would lower their average home bias. Until now, it was not possible to gauge whether *what* countries produced was an important determinant of average border effects. I find that differences in specialization patterns do not matter very much. Rather, per capita incomes appear to be the most important factor in determining a country's average border effect. Countries with higher per capita income have much lower border effects. The conclusion I draw is that the level of development appears to be the prime factor in explaining the differences in country-specific border effects. What countries produce is only of some importance. Therefore, we should see continued, though possibly slow, reductions in home biases as all countries continue to develop.

For the environmental regulator, these border effects mean that they need to condition their choice of regulation on the depth and importance of international trade in the industry to be regulated. If international trade is largely unimportant, then they need not consider strategic interactions between countries but do need to worry about market power at home. For instance, poorer countries need to concern themselves with how they regulate their own industries rather than be concerned with how other countries regulate theirs. Their industries are sufficiently inward orientated that the closed-economy model is a good approximation. For richer countries, strategic considerations become more important and so the need for vigilance increases. Further, the need to coordinate environmental policies might also increase. The systematic decrease in border effects across countries and industries also suggests that concerns over international competitiveness may become ever more important.

The first two essays show that traditional Command and Control regulations offer benefits over newer, incentive-based regulations that were not previously appreciated. They can lessen the impact of regulation on competition within an industry and so offer a preferred mode of intervention. This may become more important as firms consolidate capital within larger corporations. Command and Control might also enhance competition and create a double-dividend. This is less likely under incentive-based instruments. Alternatively, Command and Control instruments can diminish conflict between nations by preserving competition in international markets.

The third essay shows that we need to be aware of how countries and industries differ. International competition for markets is not ubiquitous. Regulation needs to reflect this. Broad-based institutional reform can be misguided if it does not incorporate national and industry specific characteristics. In particular, it is unwise, as Bhagwati (1996) points out, to force all countries to share the same level of emissions. In a similar vein, it is equally unwise to force all countries to share the same kind of regulatory framework.

CHAPTER 2: ENVIRONMENTAL STANDARDS AND MARKET STRUCTURE

2.1 INTRODUCTION:

This chapter analyses the effects on market outcomes of imposing a broad range of Command and Control regulations under different market configurations. Economic analysis of instrument choice has primarily focused on comparing non-tradable emission permits with emission taxes or with tradable emission permits.[1] This focus, though important, is also somewhat distracting as the preponderance of regulations is likely to remain of the Command and Control sort. Unfortunately, we do not typically differentiate between different modes of Command and Control. We often presume they are all equivalent. As a consequence, there does not seem to be a full understanding of how these traditional regulations impinge on market outcomes. As long as Command and Control continue to be a major component in the regulator's arsenal, we need to understand how they alter market behaviour so that we can better choose among them.

In this chapter I show how different modes of regulation, interacting with different market structures, affect industry output, abatement costs, profitability, optimal targets, and social welfare. Control regulations are not equivalent since they alter market outcomes by altering the degree of competition between firms. I compare four instruments, identified by Helfand (1991), that cover the broad range of quantitative restrictions:

- *Emission Standards* that mandate maximal emissions per firm,
- *Design Standards* that mandate minimum abatement expenditures[2],
- *Concentration Standards* that mandate maximal emissions per unit of output, and
- *Output Standards* that limit output of the firm.

I make three points of comparison. First, I compare characteristics of each instrument under different market conditions: Perfect Competition, Monopoly, and Cournot

[1] See Baumol and Oates (1988) and Spulber (1985) for a discussion under Perfect Competition. Ulph (1992, 1994, 1996) and Copeland (1992) have examples under Imperfect Competition. Most undergraduate textbooks in Environmental Economics also make this comparison.

[2] This is the formulation used by Besanko (1987). An alternative formulation is to assume that the production and abatement process used by each firm is fully specified by the regulator. This formulation of a Design Standards can impose higher marginal costs on the firm but need not imply minimum abatement expenditures. However, this form of regulation is very close, in effect, to that of the Concentration Standards since it places no direct constraint on emissions or output but does raise marginal costs at all output levels.

Competition. Second, I compare outcomes from regulated industries to those of unregulated industries. Third, I compare and rank instruments given both arbitrary and optimal targets.

The primary mode of analysis is graphical. This illustrates the regulator's problem in a simple way. It captures the tension between enhancing environmental quality and potentially worsening market outcomes. The aim is to assess the impact of regulation on the degree of competition within an industry and how regulators might adjust targets and/or the mode of regulation as a response to that competition. I restrict my analysis to a static, closed economy where the number of firms is fixed. I have ignored the political economy aspects of instrument choice and suppose the regulator is a simple optimizer. The results presented are a necessary first step in understanding the political forces that might impinge on the choice of instruments. It identifies the potential winners and losers and so identifies possible areas of conflict and coalition building that can arise in the formation of a coherent environmental policy. I have also ignored the issue of firm entry and exit. Again, this static framework is the first step in identifying the entry and exit pressure that can arise under the different forms of regulation.

With this framework, I obtain some new results:

1 Standards can be ranked. The ranking is a function of market structure:

- Design or Concentration Standards offer a Potential Pareto Improvement over Emission Standards as long as the market price, in equilibrium, exceeds firms' marginal compliance costs.
- Emission Standards are always dominant under perfect competition.
- Output constraints are never an efficient mode of regulation.

2 Firms need not be entirely averse to regulation:

- Output and Emission Standards can raise profits above unregulated industries.
- Concentration and Design Standards typically lower profits.

3 Firms differ in how they rank standards:

- Perfectly competitive firms and Cournot Competitors prefer to be regulated by Output constraints.
- Monopolists prefer Emission Standards.

- None prefer Design or Concentration Standards.

4 When abatement activities reduce marginal production costs (cost-complementarities), regulation using Design, Concentration, or Emission Standards can enhance competition and raise market output.

- This can yield a "double-dividend" where both social surplus and environmental quality rise.
- The double-dividend cannot occur in perfectly competitive markets. It can only occur under market power.
- The double-dividend is more likely under Design Standards though possible under Emission and Concentration Standards.

The results contained in this chapter add considerably to existing results comparing instrument choice. Helfand (1991), for instance, analyzed a wide range of controls but did so only under a price-taking assumption. She did not extend her analysis to imperfectly competitive markets. She ignored the effect regulations have on *how* firms interact. Many of the industries that are most directly affected by environmental regulations, such as pulp and paper, industrial chemicals, electrical generation, and primary metals, are better characterized as oligopolistic rather than perfectly competitive hence a better understanding of how regulations affect firm interaction is important. Besanko (1987) on the other hand considered, as I do, different standards under Cournot Competition. He showed that *optimally set* Design Standards could be more efficient than Emission Standards. He did not identify sufficient conditions for this to occur. I show why and when this can happen and so gain better insight. I also consider a broader range of standards. As noted in Chapter 1, Concentration Standards are an important form of regulation and so need to be analyzed. Further, I compare standards for arbitrary targets as well optimal standards. This is important since regulations are not always characterized as efficient (Potier, 1996, p. 16). Finally, I am able to identify the possibility of a double-dividend and show that it is, partially, a *function of* the form of regulation. This latter point has not been made before.

The layout of the chapter is as follows. In Section 2.2 I present the basic model under Emission Standards. I show the output, abatement, profit, and social welfare effects of binding targets under perfectly competitive markets and under monopoly. I find and compare the efficient targets under those two market structures. I illustrate the tradeoff facing regulators between stricter targets and output restrictions thus motivating sub-Pigouvian taxation in Imperfectly Competitive markets. In Section 2.3 I look at Design Standards. I again show the output, abatement, profit, and social welfare effects of binding targets under competitive markets, monopoly, and oligopoly. I then compare these effects, and those under optimal policies, to that found under Emission Standards in Section 2.4. I illustrate the tension between Design and Emission Standards and derive sufficient conditions under which Design Standards dominate Emission Standards. I also present a numerical exercise exploring these points. Results here are consistent with Besanko. In Section 2.5 I extend the analysis to incorporate the possibility of cost complementarities between marketed outputs and abatement activities. I show that binding regulations can lower marginal costs despite higher average costs. This can lead to more competition than would otherwise exist in an unregulated industry. This can yield a "double-dividend": higher social surplus and lower pollution. I show that output must be below the social optimum for this to arise. The rise in social surplus is more likely under Design Standards than under Emission Standards. In Section 2.6 I look at Concentration Standards. In Section 2.7 I consider at Output restrictions as a mode of regulation. In both these sections, I compare results to that under Emission and Design Standards. Concluding remarks are in 2.8.

2.2: EMISSION STANDARDS

In this section I develop the basic model and show the effects of a binding Emission target on the level of output, abatement, profits, and social welfare. The focus is the introduction of a simple graphical tool that illustrates the tension between increased environmental stringency and market output. I begin with arbitrary targets under different market structures then turn to optimal targets.

2.2.1 The Basic Model

A primary focus of this chapter is to highlight the role environmental regulation has on the cost structure of firms and how changes in those costs alter the interaction between firms. The best way to feature this is to think of the firm's output and abating activities as separate activities in a joint production process. Output (q) is a marketed product while abatement (a) is non-marketed activity that reduces the amount of emissions or the damage they cause. The firm's problem is to choose its profit maximizing levels of output (q_j) and abatement (a_j), given rivals' output (q_{-j}) and the regulatory environment. Since abatement is non-marketed, the firm engages in it only because it allows the firm to satisfy their regulatory obligations.

Taking output and abatement as joint products introduces the possibility of cost complementarities and anti-complementarities in simple fashion. The cost equations derived from joint production summarize the interaction between production and abatement. For instance, Baumol, Panzar, and Willig (1982) consider cost-complementarities and motivate the underlying technology by considering the case of quasi-public inputs that can be used by two production lines without complete congestion (p. 78). In their formulation each production activity uses rival inputs (v) and a quasi-public input (k) such that $C(q, a) \equiv V(q, a, k) + \psi(k, \beta)$. V is the minimum variable cost of producing outputs q and a given k units of some capital services. The capital service cost function $\psi(k, \beta)$ represents the cost of acquiring k units of the capital service at factor price β. If k is perfectly rival, then no complementarities exist and the firm has only weak economies of scope.

For the purposes of this chapter I will assume $C^j(q,a)$, is convex and twice-differentiable with costs strictly rising in q and a at non-decreasing rates. Baumol *et al* discuss necessary conditions for this to hold (p 52-55). This cost structure is still rather general. To make it more concrete and to focus on how regulations alter firm interaction I begin with the simplifying assumption that no complementarities exist. Importantly, this means that abatement activities do not affect marginal (production) costs. Specifically, $C^j(q,a) = C(q) + D(a)$ where $C(q) \equiv min_v \{ v\, w |\, g(v) \geq q\}$ and $D(a) \equiv min_v \{ v\, w |\, h(v) \geq a\}$. Inputs ($v$) have exogenous factor prices w. Production technologies are $g(v)$ and $h(v)$. The assumption of non-complementarities permits a simplified graphical representation that shows how regulations impinge on a firm and how modes of regulations differ.[3] It does not materially alter results. I relax this assumption in Section 2.5.

[3] In the numeric example used later I let $C(q,a) = c\, q + d(a^2)/2$. The important point is that abatement will not change marginal costs. One can consider the case where marginal abatement costs are increasing in output while marginal costs are independent of abatement. This modification is trivial and has no effect on the results reported here. Besanko uses a different formulation where abatement costs are independent of output but marginal costs are rising in abatement. The difficulty with that formulation is that the marginal cost curves

Firms are identical. An important part of the comparison between regulations that has taken place is based on differences across firms in terms of their abatement opportunities. I chose to abstract from this non-homogeneity for two reasons. First, I want to identify how control regulations differ in the simplest possible model. There are already two types of distortions in my model so adding a third distortion would be too distracting. Second, assuming firms are identical isolates how regulations alter the degree of competition between firms. When firms differ, say in size or costs, regulations will change the *relative* positions of firms by altering competitive pressures. For instance, regulations might benefit larger firms more than smaller firms and so enhance their competitive advantage. Alternatively, regulations may restrict larger firms more than smaller firms. The symmetric application of regulations to asymmetric firms is an interesting question by itself and does lead to some novel results. I leave these to future research.

I assume each firm chooses their output and abatement decisions simultaneously (Cournot Competition). This is the simplest way to isolate the effect each regulation has on the degree of inter-firm competition. In this Cournot framework, no firm has a competitive advantage over its rivals so regulations affect all firms equally. An alternative and interesting assumption is to suppose non-symmetric competitive advantages such as a Stackleberg Game. The symmetric application of regulations can enhance or diminish a firm's advantage.

Emissions have no productivity spillovers. Each firm faces identical regulations[4]. Marginal revenues, for a given sum of rival outputs, are positive, non-increasing in q, and decreasing in rival outputs. Hence, each unregulated firm's reaction function is downward sloping. I also assume that industry revenues are strictly concave in industry output. This implies that any rise in industry output, above the joint profit maximizing level, will unambiguously reduce industry profits given the convexity in costs. Abatement is a non-priced service flow so only benefits the firm to the extent that it permits additional output.

become endogenous and so complicate figures considerably. I take up this cost anti-complementarity in section 2.5.

[4] Since I assume all firms to be identical, an equal allocation of non-tradable emission permits is an optimal policy. If firms differed, say in abatement technology, then the efficient allocation of non-tradable permits would be asymmetric. This, of course, is precisely the problem with implementing C&C regulations when firms differ. It is not efficient to treat all equally if each differs in its ability to comply with regulations. This is exactly Kalt's (1985) point.

Entry is not possible so firms can retain positive profits. One can view the following results as either a short-run analysis or characterizing industries with significant barriers to entry.

Each firm's emissions are a function of its own output and abatement: $e^j(q_j,a_j)$. I assume that emissions rise with output at a non-decreasing rate and fall with abatement at non-increasing rates. I also assume that emissions, absent abatement, are bounded above for all output levels. This ensures that if emission targets are high enough, then no abatement is required.[5] For the figures used in this chapter I assume that $e = q - a$. This allows me to plot both output and emissions in the same figure since they can be measured on the same scale. This simplifies the figures without introducing too much clutter. The results derived in this chapter are not conditioned on this assumption.

Environmental damages rise with industry emissions at non-decreasing rates.

I assume that the regulators wishes to maximize the sum of Social Surplus (Consumers' and Producers' Surpluses) less emission damages. This is the standard problem used in this literature. Regulators attain the optimum by stipulating maximal emissions for the industry. The regulator has perfect information so can achieve its target industry emission level by choosing appropriate firm specific targets. Later, in comparing instruments, I assume the regulator can attain targets with any of the alternative controls[6].

2.2.2 The Firm's Problem under an Emission Constraint

The j th firm's maximization problem can be written as:

$$\mathbf{Max}_{qa}\ \pi^j(q_j,a_j,q_{-j}) = R(q_j,q_{-j}) - C(q_j) - D(a_j)$$

Subject to the following constraint: $\mathbf{e(q_j,a_j) \leq E^j}$. E^j is the firm's specific emission target.

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[5] This assumption imposes a restriction on the structural form of the abatement technology. For instance, if abatement were characterized by $e = q/a$, then zero abatement yields infinite emissions and damages.

[6] It is important to note that differentiation between instruments may, in fact, be more nominal than real. Besanko, for instance, points out that, if the regulator cannot measure emissions, then they may rely on installed equipment as a sign of compliance. Hence the Emission regulation is effectively a Design Standard. Alternately, if abatement equipment is costly to operate, and utilization cannot be directly monitored, then the regulator may use emission data to ensure the firm is using its equipment as specified and so the Design Standard is really an Emission Standard (p. 24). Another problem is that if the abatement technology has a fixed cost component, then Emission Standards may not differ from formulation of Design Standards used in this model. The intuition presented in this paper is easily mapped into these situations.

We can solve the first order conditions for an interior solution under the assumption that the constraint is binding. First, define *marginal compliance costs* as marginal costs inclusive of abatement costs that hold the firm in compliance with regulations. Denote this as C_q^P. This yields the following first order conditions:[7]

(E) $$\mathbf{R_q = C_q(q) - D_a(q,a)\,[e_q(q,a) / e_a(q,a)] := C_q^E\,(q,a(q,E)).}$$

In (E), the optimal choice of abatement becomes a function of output, given the emission constraint. The firm can alter both output and abatement but has only one degree of freedom. It's easiest to think of the firm as choosing output and then varying abatement to comply with the constraint. Condition (E) is then readily interpreted. In an unregulated market, the firm chooses output so that marginal revenues equal marginal costs. Abatement is zero since it is costly and yields no direct benefit to the firm. With (E), the firm chooses output, and abatement, so that the increase in revenues from additional output just equals the increase in costs of raising output while maintaining compliance with the emission restriction. If the target is binding, $e(q_j,0) \geq E^j$, then expansion of output must be accompanied by additional abatement. This raises costs above pure production costs since $D_a>0$, $e_q>0$, but $e_a<0$[8]. If the emission constraint is not binding, then marginal compliance costs equal pure production marginal costs. By construction there is a particular output level, denoted Q(E), at which the emission constraint becomes binding without abatement. The higher the allowable emissions, the higher the output level at which the target binds, hence the closer the regulated and unregulated firms become or, alternately, the greater the range of output for which no abatement is undertaken.

2.2.3 Market Equilibrium under Binding Emission Targets

Given the market demand and fixed number of firms we can derive the market equilibrium levels of output, abatement, profits, and social welfare. It is easy to show the effects of a binding emission target on firm, and industry, behaviour. I begin with the limiting case of a competitive industry where each firm is a price taker. This is the analogue

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[7] Besanko denoted the Emission Standard as a Performance Standard. For clarity I will use the superscript E to refer to Emission Standards.

[8] Note the equivalence between Emission Taxes and Emission Standards if taxes are set equal to $[D_a(q,a)\, e_q(q,a) / e_a(q,a)]$, evaluated at the equilibrium output. Output and abatement are the same under either regime. Profits differ by the amount of taxes collected. This allows us to compare C&C standards directly with tax-based instruments. This equivalence does not necessarily hold in dynamic frameworks (see for example: Copeland (1992) or Ulph (1992,1996)).

to Helfand's analysis and a good starting point for analysis. I then consider the Monopoly and Cournot case.

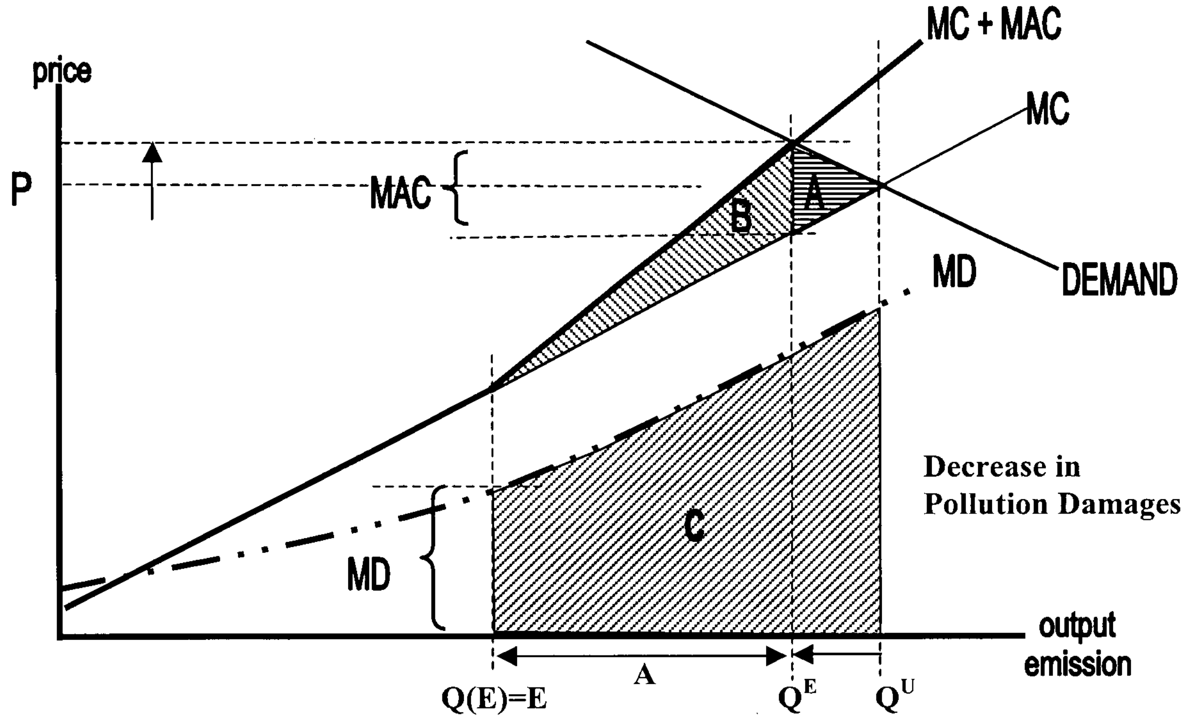
2.2.3.1 Price Taking Firms

Consider an industry made up of identical, atomistic firms facing a downward sloping market demand curve. Each firm faces an upward sloping marginal cost curve and, from their individual perspective, a horizontal demand curve. This is equivalent to assuming that the demand curve is the firm's marginal revenue curve and average revenue curve. Market equilibrium occurs where the firms' marginal cost curves cross their marginal revenue curve. Denote this as the unregulated industry output Q^U. This is depicted in **FIGURE 2.1.** Also depicted is the marginal damage curve for the industry. This is increasing in industry emissions. As noted previously, I assume for diagrammatic purposes only that emissions rise one-for-one with output and falls one-for-one with abatement: $e = q - a$. At the unregulated equilibrium abatement is zero so emissions equal industry output. Marginal damages are positive.

Now suppose the regulator imposes a non-optimal, but binding, industry emission target uniformly across all firms. The firm can choose to produce above Q(E) but must abate so that emissions do not also rise. The marginal compliance costs are depicted as the kinked marginal cost curve (MC + MAC). Firms maximize profits by choosing output (and hence abatement) that sets their marginal compliance costs equal to the market price. As depicted, each firm reduces output from Q_U to Q^E and raises abatement from zero to A. Emissions, however, fall more than output. The reduction in industry output raises the market price.

The net welfare effect is divided into two components. The first is a loss in consumer and producer surpluses. Consumers lose due to the higher price. Producers increase abatement costs and also lose output. The sum of these losses is area A and B in the figure. At the margin, the decrease in Social Surplus is exactly equal to the firms' marginal abatement costs (MAC). That is; firms choose the combination of abatement increases and output restrictions so that the additional costs of abatement is exactly equal to the additional cost of reducing output. Hence marginal abatement costs are equal to losses in net marginal Social Surplus. The second component is the decrease in pollution damage. This is the trapezoidal area C. At the unregulated output, the decrease in pollution damage (MD) is larger than the increase in MAC, which is zero. Hence, a small binding target raises welfare.

FIGURE 2.1: EMISSION STANDARDS under PERFECT COMPETITION.



The effect on firms' profits is ambiguous. Profits may rise if the rise in price raises revenues more than firms lose in terms of lower output and increased abatement costs.[9] This is the case depicted in **FIGURE 2.1**. This effect depends on the elasticity of demand as well as marginal abatement costs. The higher the elasticity of demand, the lower the likelihood that regulation can raise profits. Similarly, the lower the marginal abatement costs, the smaller the effect on output, and so the less likely regulations raise industry profits.

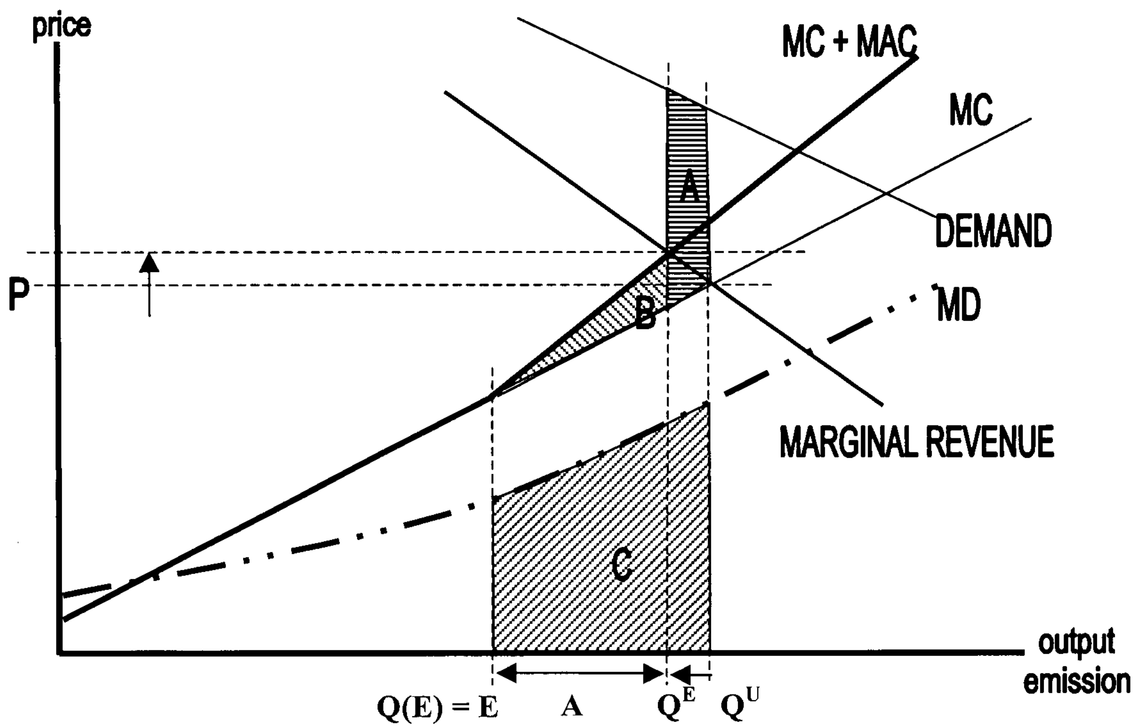
2.2.3.2 MONOPOLY:

Now consider the case where firms can affect the market price. By construction, any unregulated Cournot Competitor will have the usual downward sloping reaction function. A firm regulated by a binding Emission Standard will have the same reaction function for outputs less than Q(E) but, since it faces higher marginal costs above this, its reaction function will rotate inwards at this point. The net effect is a restriction in output and higher market prices.

[9] This is not a novel result. See Buchanan and Tullock (1975) for an example.

We can get an idea of the problem facing the regulator by looking at the simpler Monopolist's problem. **FIGURE 2.2** shows the same industry conditions as **FIGURE 2.1** but under monopoly control. An unregulated monopoly produces at Q^U with zero abatement. Notice that the firm willingly restricts output and so reduces environmental damages. As depicted, however, the marginal damage is still greater than zero and so the regulator needs to consider whether to restrict emissions further. The regulator's problem is that output has also fallen implying a lost social surplus. Any further reductions in output reduce that surplus.

FIGURE 2.2: OUTPUT, EMISSIONS, and ABATEMENT under MONOPOLY.



Imagine if the regulator chooses the same emission target as in **FIGURE 2.1**. The monopolist maximizes profits at output Q^E where their marginal compliance costs are equal to marginal revenues. The cost to society is the lost producer and consumer surplus. This is area A and B in the figure. The benefit is the reduction in damages (area C).

At the margin, the loss in Consumer and Producer Surpluses is the vertical distance between the market price and the firm's marginal cost curve (P – MC). Note that at the unregulated equilibrium this is positive whereas it was zero under Perfect Competition. The decrease in welfare (excluding the benefits of reduced damages) from the binding regulation is greater than the rise in the monopolist's marginal abatement costs. At the unregulated output as depicted, the decrease in pollution damage (MD) is larger than the increase in (P – MC). Hence, a small binding target raises welfare in this case.

Monopoly profits, of course, fall with regulation since the firm could abate but chooses not to if unregulated.

2.2.3.3 Cournot Competition:

We can extend the intuition directly into the Cournot case under the assumption that all firms remain profitable in equilibrium. The difference is that the wedge between market price and marginal compliance costs will fall as the number of firms rise. The basis of the analysis remains. The cost to society of imposing a binding target is larger than the marginal abatement costs of the individual firms. Only in the limiting case of perfect competition will marginal social costs equal marginal abatement costs.

Industry profits, as under Perfect Competition, can rise. The issue here is that firms compete head to head and so dissipate profits. Regulations change the degree of competition and, by reducing competition, can benefit firms[10]. The firms would like to restrict joint output but, if unconstrained, are not able to credibly commit to lower output levels. Each has an incentive to expand output. Regulations raise marginal costs and do for the firms what they could not do for themselves; facilitate collusion by coordinating, and enforcing, lower output levels.

Normally, a rise in marginal costs results in lowered profits except under some special demand conditions. The effect of regulation is slightly different in that it raises marginal costs *at the margin* rather than along the entire marginal cost curve. Infra-marginal costs need not rise at all since the target is non-binding at low output levels. The firm's mark-up over marginal costs fall as regulations are imposed but their <u>average markup</u> can rise. Whether profits rise depends on the market elasticity of demand, the stringency of

[10] This idea that constraints on firms' activities alter profitability parallels the idea of Vertical Restraints in the Organizational Behaviour literature. See Mathewson and Winters (1984) and Tirole (1990) for an introduction. The problem there is that a manufacturer, with downstream retailers, has an incentive to modulate the degree of competition between its retailers so as to extract more rents. It can do so in many ways. For instance, it can design supply contracts that stipulate minimum retail prices, exclusive territories, or franchise fees. The profit maximizing restraint is a function of both the type and strength of interfirm competition. By contrast, the regulator in this paper is not attempting to shift any rents. The underlying idea remains: regulations alter the way in which firms compete. This alters their profits in a way that they could not achieve themselves.

targets, and the abatement technology[11]. Note that an emission tax raises marginal costs at all output levels and so tends to reduce both the marginal markup and the average markup.

2.2.4 Optimal Emission Targets

The discussion above describes the effects of imposing an arbitrary emission target on an industry. The critical insight is that the firm's marginal abatement costs, under market power, under-estimate the social cost of imposing a binding target. In picking an optimal emission target, the regulator must balance the cost of reducing industry output with the benefit of reducing emission damages (MD). The cost is a function of the degree of market power enjoyed by firms.

2.2.4.1 Optimal Emission Targets under Price Taking Assumption:

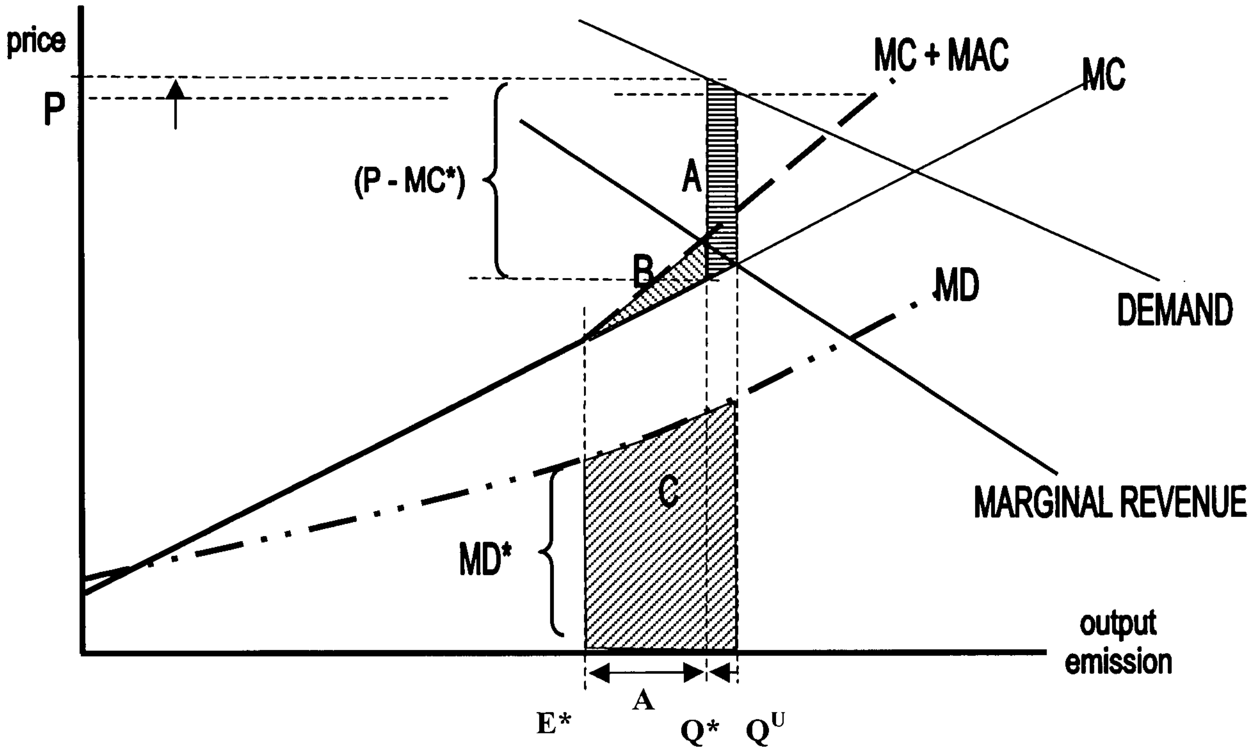
Under the price taking assumption, the optimal target sets MD equal to MAC. That is, the regulator chooses E so that the increase in social losses (measured by MAC* at the industry's equilibrium output) is equal to marginal damages (MD*). **FIGURE 2.1** shows a sub-optimal target. The optimum is stricter. This optimal target is a function of the demand elasticity, marginal abatement costs, and marginal damages. It is also possible to show that the optimal target becomes more stringent as marginal damages rise, marginal abatement costs fall, and demand becomes more elastic.

2.2.4.2 Optimal Emission Targets under Monopoly:

Again, the regulator's problem is to choose the emission target so that any further output restrictions are balanced by reductions in emission damages. However, the regulator needs to account for the fact that the change in social surplus is a multiple of MAC. The regulator chooses E so that the increase in social losses (measured by (P-MC) at the firm's equilibrium output Q^E) is just equal to their marginal damages (MD). This is depicted in **FIGURE 2.3** below. This has the same demand and costs as **FIGURE 2.2**. The net social gain is area C less area A and B.

[11] In fact, it was difficult to construct numerical examples in which a relatively lax, but binding constraint, DID NOT raise profits above unregulated firms. Profits would fall if the constraint were severe.

FIGURE 2.3: OPTIMAL OUTPUT, EMISSIONS, and ABATEMENT under MONOPOLY.



Note that, at the optimum, marginal damages exceed marginal abatement costs under monopoly. This is the point made by Katsoulacos and Xapapadeas (1996), Barnett (1980), and Cropper and Oates (1992) among others. Regulators need to impose slacker standards since the firm is producing too little from a social standpoint. Stricter standards make the output distortion worse.[12] **FIGURE 2.3** shows the intuition and how marginal costs, demand elasticities, and abatement technologies interact at the optimum. The corollary is that the optimal target is necessarily slacker for a monopoly than for perfectly competitive firms since (P- MC) > MAC. This can be stated as a proposition.[13]

PROPOSITION 2.1: *The Optimal Emission Target is slacker under Monopoly than under Perfect Competition.*

Proof: See Appendix II for all proofs.

[12] Cropper and Oates (1992, p. 685), following Barnett (1980), show that the optimal emission tax is equal to $t^* = t_c-[(P - MC)\ dQ/dE] < t_c$ where t_c is the optimal tax under perfect competition and dQ/dE is the induced reduction in output from a unit decrease in the emission target. The smaller optimal tax implies a slacker target for the monopolist.

[13] This proposition need not hold when there are cost-complementarities. See section 2.5 below.

Proposition 2.1 also extends to Cournot Competition since, there too, (P-MC) > MAC for each firm. In the limit, however, the emission target for a Cournot industry converges to that for Perfect Competition since price converges to marginal compliance costs.

2.3: DESIGN STANDARDS

In this section I show the effects of a binding Design Standard on the level of output, abatement, profits, and social welfare. I later compare these directly to Emission Standards and assess which mode of regulation is preferable depending on the degree of industry competition. I also compare results to an unregulated market.

Design Standards differ from Emission Standards in the way compliance costs enter the firm's cost structure. In the specification I employ, Design Standards turns what is a variable cost under Emission Standards into a fixed cost.[14] Hence output becomes independent of the target emission level. Note that the fixed costs nature of Design regulations is a result of the form of regulation and not the abatement technology. Actual expenditures may take place all at once or over time. For instance, the firm may have to install new equipment (a fixed investment) or engage in ongoing activities such as maintain a tailings pond (a variable cost). The important point is that the firm, at the time it decides to remain in operation, is committed to a course of action that entails some unavoidable expenditure. Under Emission Standards, the firm could avoid those expenditures by reducing output sufficiently.

This fixed cost requirement implies that Design Standards may dominate Emission Standards under some conditions. It also implies possible multiple equilibria since the fixed costs will create a discontinuity in each firm's reaction function. I explore these in turn.

2.3.1 The Firm's Problem under Design Standards

The regulator stipulates the firm's abatement technique, hence minimum abatement costs, but imposes no other restrictions on emissions or output. The Design regulation, hence, takes on an aspect of a licensing requirement. As long as the firm engages in the required abatement activities it is allowed to operate. The regulator is able to deduce the

[14] Besanko (1987) also uses this specification.

abatement requirement needed to attain a particular emission target since it can foresee the equilibrium level of output.

The j th firm's maximization problem can be written as:

$$\mathbf{Max_{qa}\ \pi^{j}(q_j, a_j, q_{-j}) = R(q_j, q_{-j}) - C(q_j) - D(a_j)}$$

Subject to the following constraint: $\mathbf{A_j \le a_j}$ A_j is the firm's specific abatement target that it must achieve. Solving yields the following first order conditions: $\mathbf{R_q = C_q(q_j) := C^D{}_q(q)}$. This condition says that the regulated firm has the same marginal costs as an unregulated firm since abatement and output costs are separable. The additional abatement cost raises average costs but not marginal costs. Hence the imposition of Design Standards has no output restricting effects (except possibly under Cournot Competition discussed below).

2.3.2 Market Equilibrium under Binding Design Standards

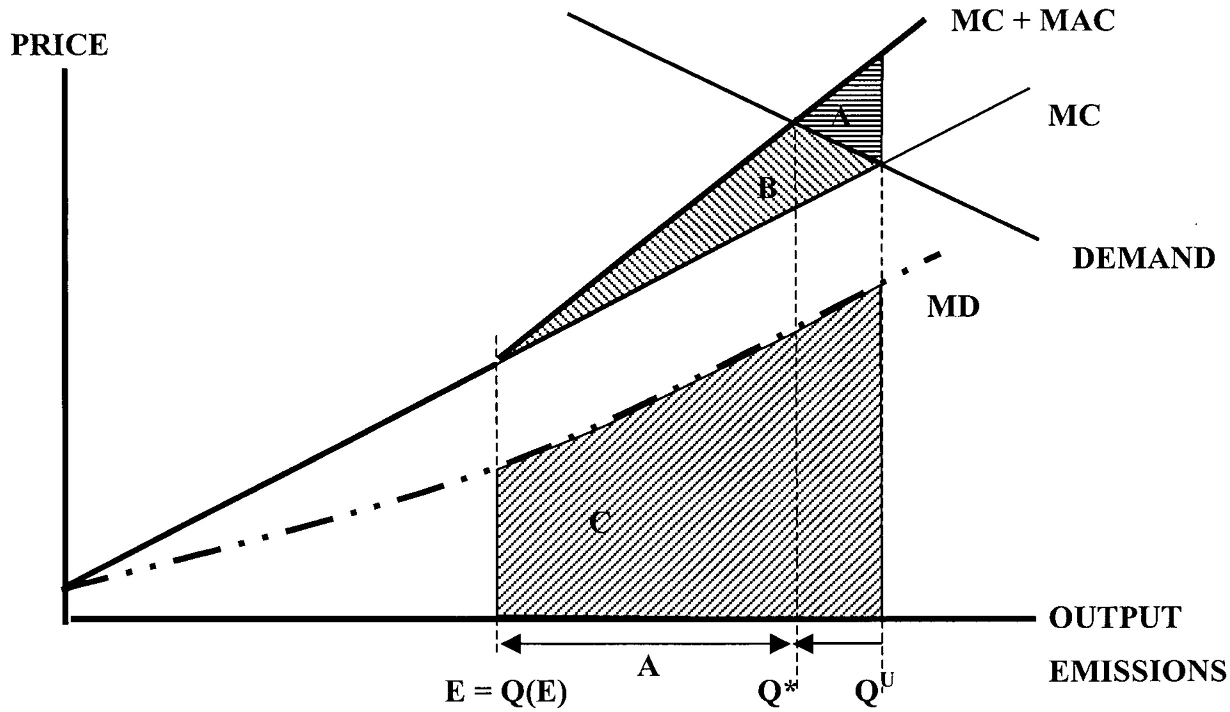
2.3.2.1 Price Taking Firms and Monopoly

Consider an industry made up of identical, atomistic firms with unregulated industry output Q^U in **FIGURE 2.4** below. This figure is identical to **FIGURES 2.1-3** in costs, demand, and pollution damages. Now suppose the regulator imposes a non-optimal, but binding, industry target. Say at the same level as in **FIGURE 2.1**. Each firm's output is unchanged since marginal compliance costs do not rise. However, their average costs have risen. We can infer the change in the firms' total costs as the area under the marginal compliance curve for identical firms regulated by Emission Standards but *who choose not to reduce output*. This total cost is area (A + B) in **FIGURE 2.4**. We can reinterpret the marginal compliance costs under Emission Standards as the true *social marginal compliance cost*. Denote this as $C^E{}_q(q^D,a^D)$. This is the marginal cost to society of choosing target E under Emission Standards. Hence social marginal costs exceed the private marginal costs under Design Standards. It's easy to see that the imposition of the target raises industry compliance costs above those from Emission Standards. The benefit is that there is more output.

The net welfare effect is again divided into two components. The first is a loss in Producer Surpluses. There is no lost Consumer Surplus. At the margin, the decrease in Social Surplus is exactly equal to the change in firms' abatement costs. Hence marginal abatement costs are equal to losses in net marginal social surplus. The second component is the decrease in pollution damage. This is the trapezoidal area C. At the unregulated output, the decrease in pollution damage (MD) is larger than the increase in MAC, which is zero. Hence, a small binding target raises welfare.

The effect on firms is unambiguously bad. Industry profits fall. This effect is independent of elasticity of demand or marginal abatement costs.

FIGURE 2.4: OUTPUT, EMISSIONS, and ABATEMENT under DESIGN STANDARDS and PERFECT COMPETITION:



What about monopoly control? First, monopoly production is unaffected by the Design Standard. It has the higher compliance cost for a given target so does cost more than Emission Standards. Second, the social marginal costs are equal to MAC and not (P – MC). This is because prices do not rise and so the only effect is on firm's compliance costs. These differences lead to differences in welfare under arbitrary targets and under optimal targets. I discuss these later.

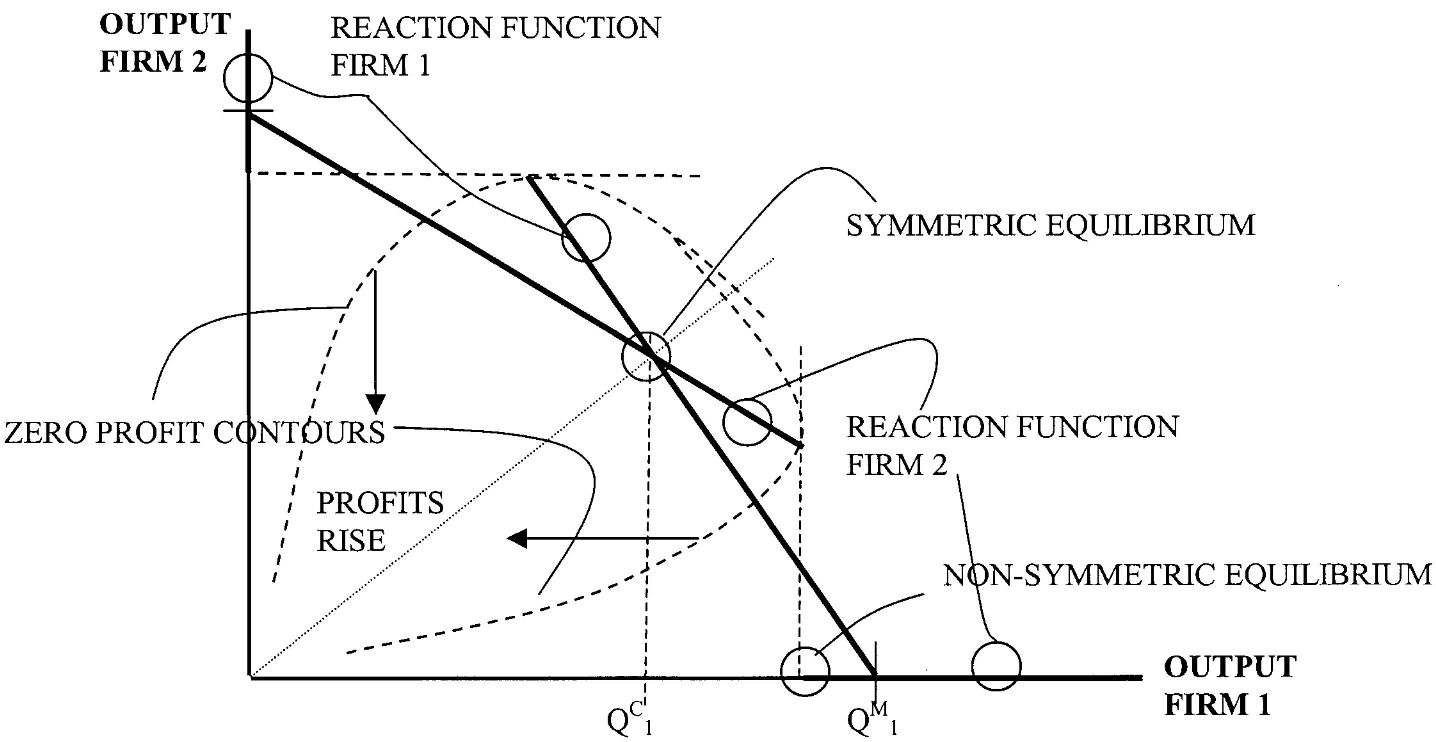
2.3.2.2 Cournot Competition.

Design Standards have a qualitatively different effect on the firm's reaction function than do Emission Standards since the fixed costs nature of the regulation causes a discontinuity at low output levels. This implies the possibility of multiple equilibria that are not present under Emission Standards. Further, non-symmetric equilibria can exist alongside the symmetric equilibrium. The phenomenon can of course arise in any Cournot model with fixed costs. The important point is that the form of regulation imposes fixed costs on the firm. It is not assumed as a characteristic of the abatement technology.

I explore this possibility here but assume it away in the rest of the paper since these non-symmetric equilibria do not appear to be compelling as long as the symmetric equilibrium is profitable. It does, however, raise the possibility that the symmetric application of Design regulations can affect asymmetric firms quite differently. For instance, Design Standards can allow a Stackleberg leader to block entry of a competing firm where such blockage was not possible under Emission Standards. Again, the mode of regulation interacts with the form of competition to generate quite disparate results.

The imposition of Design regulations has no effect on a firm's marginal costs, only average costs, and so their reaction functions have the same downward slope as unregulated firms. **FIGURE 2.5** illustrates the case for duopolists with linear reaction functions. These reaction functions coincide with the unregulated firm's at higher output levels. As rival output grows, each firm's best response is to reduce its own output. At some output level though (denoted q^s), because it must incur fixed-abatement expenditures, the firm will earn zero profits and so produce nothing. That is, it does not choose to enter the market and so output falls from a strictly positive amount to zero with only a marginal increase in rival output. This discontinuity does not occur with Emission Standards. The location of the discontinuity depends on the stringency of the environmental target and how costly that target is to achieve. The more costly it is for the firm to satisfy the standard, the higher its output must be to maintain positive profits. Note that it is very possible that only one firm is viable in a market. I avoid this by assuming that, in any symmetric equilibrium, all firms earn positive profits. The discontinuity, however, can lead to possible non-symmetric equilibria in addition to the symmetric equilibrium. For example (see **FIGURE 2.5** again), consider a duopoly and suppose that maximal profits for FIRM 1 are zero when FIRM 2 produces somewhere in the range q^c and q^m, where q^c is the output in the symmetric Cournot equilibrium and q^m is its output as a monopolist. By symmetry, this occurs for FIRM 2 as well. By construction, if both firms produce q^c, both earn positive profits and this constitutes the symmetric Cournot Equilibrium. There also exists two, non-symmetric equilibrium in which one firm chooses its monopoly output and the other produces nothing. Both are best responses to the other's actions so also constitutes a Nash Equilibrium.

FIGURE 2.5: DESIGN STANDARDS: DUOPOLY



2.4 WELFARE COMPARISON OF DESIGN AND EMISSION STANDARDS

Consider the regulator's problem of choosing which mode of regulation, Emission or Design, it should impose to achieve a particular, possibly non-optimal, environmental target. It has sufficient knowledge so that both approaches will attain the same target with certainty. The issue then reduces to maximizing the sum of Consumer and Producer Surpluses since damages will be identical. I show that Design Standards can dominate Emission Standards as long as the number of firms is small and abatement is not too difficult. I make this more precise below. Emission Standards dominate under perfect competition.

2.4.1 Perfect Competition

Under perfect competition, the market price equals the social marginal compliance costs under Emission Standards. Hence the market achieves the socially optimal allocation of output and abatement for the given target. Under Design Standards, the social marginal compliance cost is above the market price. Firms over produce and so must abate more. Consider **FIGURE 2.4** where I show the equilibrium output under the two modes of regulation and the same target. The Emission Standard reduces market output to Q^* from Q^U. The loss in social surplus is the shaded area B. Under Design Standards, the firm maintains output at Q^U but incurs abatement costs equal to the sum of areas A and B. This is the corresponding social cost of achieving the target. Hence Design Standards impose an additional cost to society of area B and are not an efficient mode of regulation. Notice however, that as long as the emission target is relatively slack, the dead weight loss (DWL) under Design Standards will be small. There may be little to gain by moving to Emission Standards. However, as the stringency of the target rises, or compliance costs are large, the DWL rises and the superior Emission Standard becomes more important.

2.4.2 Monopoly and Cournot Competition

This model, by construction, yields the standard result that Cournot output, under Emission Standards, is below the social optimum since market price exceeds private (hence social) marginal compliance costs. The regulator's problem is to choose its preferred regime by trading consumers' benefits against compliance costs. There will be situations when the superior output characteristics of Design Standards are desirable. The following proposition offers sufficient conditions for Design Standards to dominate Emission Standards.

Domination here refers to a Potential Pareto Improvement where the sum of Consumer and Producer surpluses rises. Note that moving from an Emission to Design Standard will benefit consumers at the cost to firms. The proposition relates the final equilibrium price under Design Standards to marginal (social) compliance costs. What is important is the degree of competition in the industry and whether the Design Standard imposes large fixed costs on firms. If there is little competition and costs are relatively low, then Design Standards can dominate.

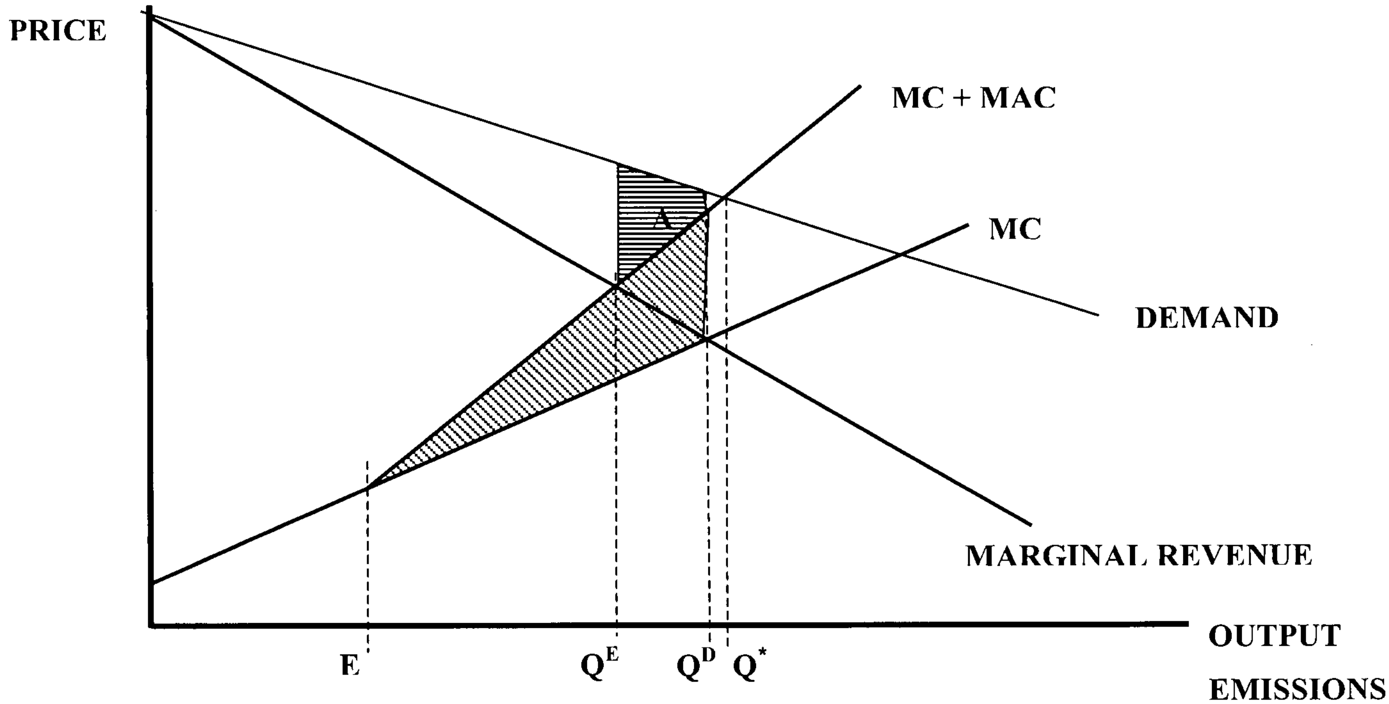
PROPOSITION 2.2 (Sufficient conditions): *Let the number of firms be fixed at $n \geq 1$ and the industry target E predetermined. Design Standards Dominate Emission Standards as long as the market price is above marginal (social)l compliance costs at the unregulated output, $C^E_q(q^D, a^D)$.*

FIGURES 2.6a and **2.6b** illustrate the basis for the proposition. These figures are similar to those used to compare the welfare differences between optimally set tax rates and emission quotas when marginal abatement costs are unknown (see Gruenspecht and Lave, 1989, p. 1517 for an example)[15].

The issue is whether the additional output one gets under Design Standards justifies the additional costs of compliance over Emission Standards. Consider **FIGURE 2.6a** where I depict a monopolist's problem under both Emission and Design Standards. The firm's optimal output, given the target E, is Q^E and Q^D respectively and the social optimum is at Q^*. Total costs are higher under Design Standards due to the higher output and abatement (this is the hatched gray area). However, as long as Q^D is less than Q^*, which corresponds to market price above marginal social costs (evaluated at Q^D), there will be a net gain in consumer and producer surplus. This is trapezoidal area A in **FIGURE 2.6a.**

[15] Their point of comparison was between excess compliance costs versus excess pollution damage. Consumer surplus was not an issue since they assume marginal cost pricing. In this paper, pollution damage in not an issue though consumer surplus is.

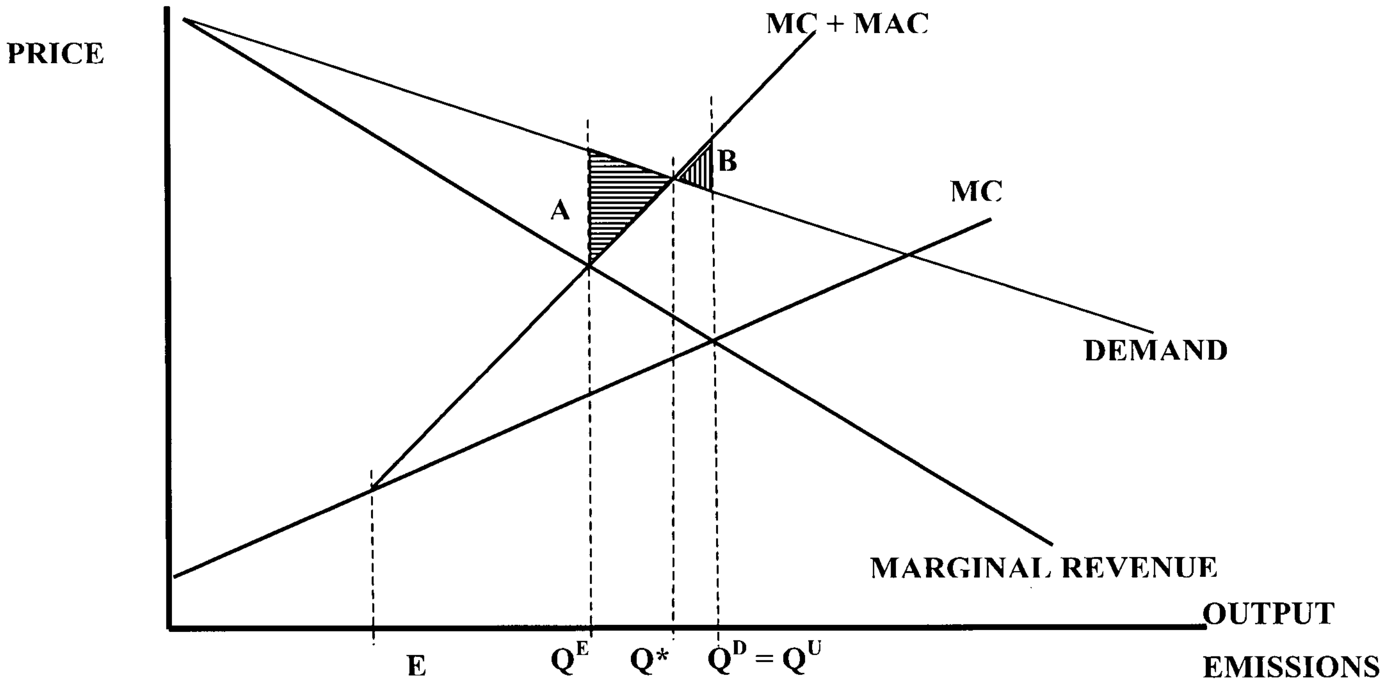
FIGURE 2.6a: EMISSION versus DESIGN STANDARDS (MONOPOLY)



Even if the conditions for Proposition 2.2 do not hold, it is still possible for the Design Standard to perform better than Emission Standards. This is depicted in **FIGURE 2.6b**. Here, the Design Standard is able to capture additional welfare (area A) that is left unclaimed under Emission Standards. Output under Design Standards, though, exceeds the social optimum. The area B, which represents losses to social surplus, is smaller than the gain (area A) and so moving to a Design Standard still represents a net welfare gain. On the other hand, if area B is larger than area A, then the Emission Standard is more efficient than the Design Standard.

Notice that Design Standards are more likely to be efficient if the emission target is relatively lax since compliance will not be difficult. This corresponds to FIGURE 2.6a. As the target becomes more stringent, however, compliance costs will rise, and the additional social costs exceed the additional consumer benefits. This is depicted in FIGURE 2.6b as a leftward shift in E. As emission targets become more stringent, the desirability of Emission Standards, or equivalently, incentive based instruments, will rise since minimizing compliance costs will become more important.

FIGURE 2.6b: EMISSION versus DESIGN STANDARDS (MONOPOLY)



Welfare results with many firms are similar to the monopoly case. The issue is whether moving from an Emission to a Design Standard is represented by the move in FIGURE 2.6a for each firm or whether it is represented by FIGURE 2.6b. We are more likely to see the case in 6a if marginal compliance costs are small, just as in the monopoly case, or if there are not too many firms. With many firms, the demand elasticity rises for each firm and so the wedge between marginal social compliance costs and price is smaller. So a move to Design Standards implies that the gain in consumer surplus is likely to be smaller than the loss in producer surplus. This is precisely case 2.6b. This is most easily considered under perfect competition (or perfectly elastic demand). With Emission Standards there is no wedge between marginal social costs and equilibrium price. Each firm is producing at the social optimum, given the emission target. With Design Standards, on the other hand, the firms' private marginal costs are lower than the social marginal costs at the social optimum. This leads each firm to over produce. Area A (from FIGURE 2.6b) is zero but area B is positive so the net benefit of moving to Design Standards is negative. As the number of firms falls, or demand elasticity falls, the wedge between the marginal social costs and price rises and so the Design Standard becomes more attractive.

2.4.3 A Numerical Example:

The above welfare claims can be illustrated using a simple numerical example. I show four experiments where Design Standards dominate Emission Standards for some range of targets and industry size. These are shown in **FIGURES 2.7a** through **2.7d.** The following parameterization is used:

- **EMISSIONS** $e(q,a) = q - a$
- **COSTS** $C(q,a) = c\ q\ + d(a^2)/2$
- **DEMAND** $P(Q) = K - s(nq)$ where n is the number of firms.

Each experiment compares welfare under Design and Emission Standards. I allow both the number of firms to vary (from 1 to 500) and the percentage reduction in emissions (from 1% to 100% of an unregulated industry). The shaded area in the upper left corner of each figure shows the combinations of industry size and emission reductions where Design Standards dominate Emission Standards. The shaded area to the bottom right is the combination of parameters where profits, under Design Standards, become negative. Profits under Emission Standards are positive for all combinations in all experiments. The area above and to the left of the dark line shows where the equilibrium market price under Design Standards exceeds social marginal compliance costs. The figures confirm that Design Standards always dominate in this region. In each experiment I fix the scale (output and emissions) of individual plants by allowing the elasticity of market demand (an inverse function of *s*) to increase as the number of firms increase. It is important to do this since I want to isolate the effects of demand elasticities on welfare rather than the effects of plant scale. As you will see below, a combination of larger scale and increasing marginal compliance costs reduces the attractiveness of Design Standards.

FIGURE 2.7a shows a baseline result with firm output fixed at 50 units under Design Standards. Firms under Emission Standards always produce less. The results also confirm that Design Standards dominate Emission Standards when emission targets are laxer and when there are fewer firms.[16] Note that with many firms and/or large targeted reductions in emissions, Design Standards will generate negative profits and induce exit. However, when this occurs, Emission Standards perform better anyway so is not an issue.

FIGURE 2.7b has results with a larger plant scale of 200. It shows that the range

[16] This is consistent with Besanko's claim although he looked at optimally set targets.

over which Design Standards dominate is smaller. This occurs for two reasons. First, the same percentage reduction in emissions requires more abatement due to the larger plant scale. Marginal abatement costs are increasing in abatement. This creates a negative scale effect where bigger firms have proportionately higher costs of attaining the same proportionate reduction in emissions as smaller firms. Second, the larger scale, given the same demand intercept (K), implies a larger elasticity of demand (smaller s). As in 7a, higher elasticity reduces the wedge between price and social marginal costs and so reduces the attractiveness of Design Standards. Together, Design Standards perform worse.

FIGURE 2.7c shows what happens when marginal compliance costs rise (the parameter *d* rises from 1 to 10). This corresponds to a more steeply sloped marginal compliance cost schedule. This confirms that, the more expensive it is to attain a particular reduction in emissions, the more likely for Emission Standards to dominate. Again, the cost savings become more important.

FIGURE 2.7d shows what happens when market demand rises (K rises from 100 to 200), holding scale constant at 50. Fixing the plant scale at 50 implies a fall in demand elasticity from the baseline case for any given number of firms. This raises the range under which Design Standards dominate since the wedge between price and marginal costs rise.

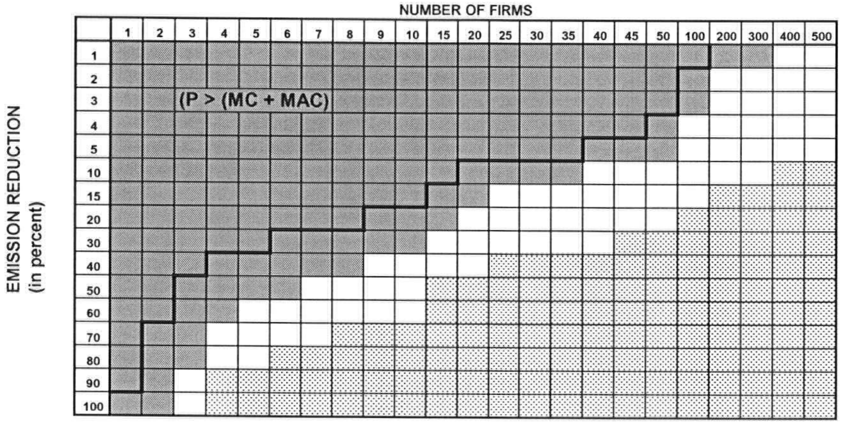
FIGURE 2.7: A NUMERICAL EXAMPLE

EMISSIONS: e(q,a) = q - a
COSTS: C(q,a) = c q +d (a^2) / 2
DEMAND: P(Q) = B - s (nq)

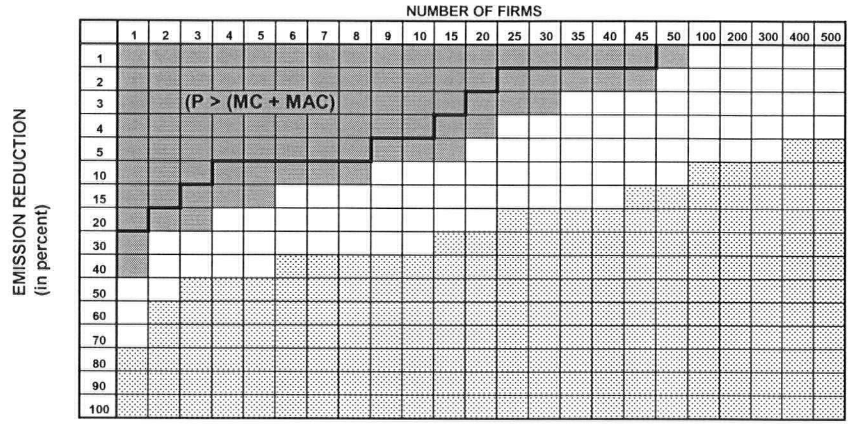
DESIGN STANDARDS DOMINATE EMISSION STANDARDS

DESIGN STANDARDS GENERATE NEGATIVE PROFITS

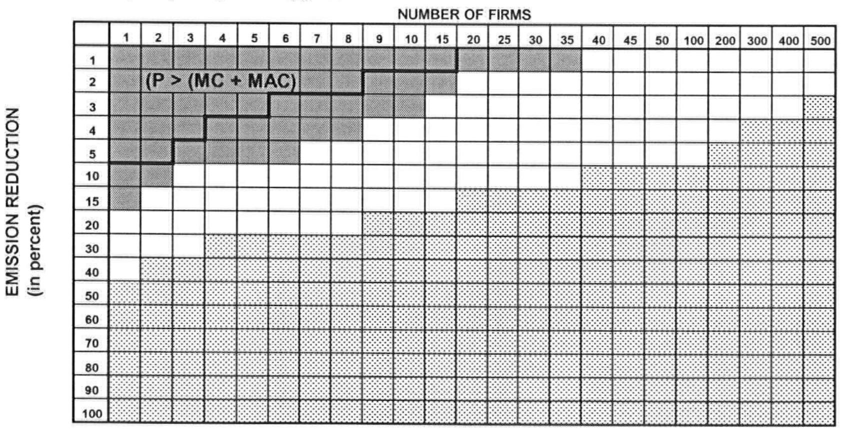
2.7a B=100, c=1, d=1, SCALE (q) =50



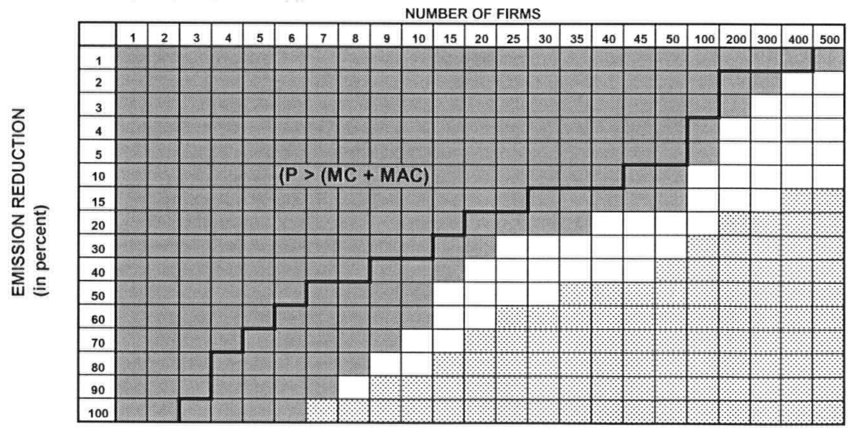
2.7b B=100, c=1, d=1, SCALE (q) =200



2.7c B=100, c=1, d=10, SCALE (q) =50



2.7d B=200, c=1, d=1, SCALE (q) =50



2.4.4 Optimal Design Standards versus Optimal Emission Standards

The results for Sections 2.4.1 to 2.4.3 were constructed under arbitrary targets. The assumption was that the regulator had a target and wanted to choose the right instrument to achieve it. I showed how Design Standards could be a sound choice. A more stringent test would be whether Design Standards could also dominate Emission Standards when each target is chosen optimally for the regulation employed. Besanko provided a numerical example in which they could. In this section, I find more general, sufficient conditions for this to hold. Second, I establish that optimal Emission targets are stricter than optimal Design Targets under perfect competition. On the other hand, I show when optimal Design targets become stricter than optimal Emission targets in Cournot Competition or Monopoly. This latter part is interesting since it suggests come conditions where environmentalists may champion one regulation over another.

As in the previous sections, we can find the optimal Design Standard that maximizes the sum of Consumer and Producer Surpluses less environmental damages. Since output is unaffected by targets, the social costs are measured purely by the MAC of the firm[17]. These optimal targets are chosen so that marginal damages are equal to marginal abatement costs where MAC is evaluated at Q^U.

Emission and Design standards, when optimally set, differ along two dimensions: in optimal targets and in industry output and costs. The choice between instruments, as in the non-optimal case looked at above, is non-trivial. I make two direct comparisons. I first consider Perfect Competition then consider Cournot Competition (and Monopoly).

2.4.4.1 Price Taking Firms

Under Perfect Competition, optimally set Emission Standards have fewer emissions and higher welfare than do Design Standards. These results are unambiguous and no surprise. They rely on the fact that marginal compliance costs under Emission Standards are equal to marginal social compliance costs.

PROPOSITION 2.3: *Under Perfect Competition:*

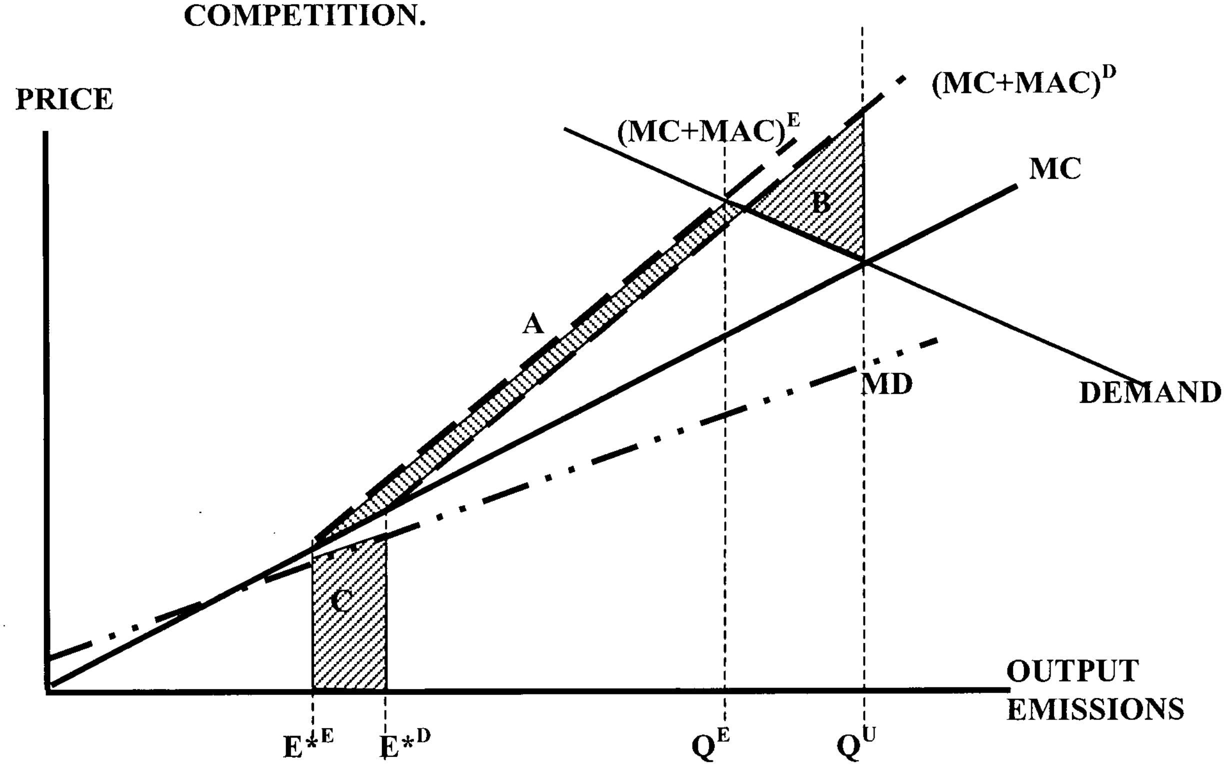
a) $E^{*E} \leq E^{*D}$ *and*

b) $W^{*E} \geq W^{*D}$

[17] Again, abatement costs are imposed as fixed costs on the firm but they are still variable costs to the regulator.

We can illustrate the dominance of optimal Emission Standards under Perfect Competition. The first is to verify that optimal targets are tighter under Emission Standards. **FIGURE 2.8** shows the optimal targets under both standards. E^{*E} is the optimal Emission target. It satisfies the condition that MAC $(Q^{*E}(E^{*E})) = $ MD (E^{*E}). If we enforce this target using Design regulation, we get MAC $(Q^{U}(E^{*E})) >$ MD (E^{*E}) since marginal abatement costs, for a given target, are rising in output. As long as MD does not decline, the optimal Design target (E^{*D}) must be slacker. Notice that as the regulator is forced to relax the Design Constraint, the marginal compliance costs curve (MC + MAC) shifts to the right.

FIGURE 2.8: EMISSION versus DESIGN STANDARDS: PERFECT COMPETITION.



The welfare effect is also unambiguous. By Proposition 2.2, Emission Standards dominate Design Standards for a given target under Perfect Competition. The regulator can impose E^{*D} using Emission Standards and so attain a higher social welfare by reducing costs. It gains area B. Its choice of E^{*E} cannot make things worse. It chooses the stricter target since the rise in social costs (measured as MAC $(Q(E^{*D}))$ is less than $\mathrm{MD}(E^{*D})$. The rise in environmental quality is area C and is greater than the additional costs (area A). Hence, optimal Emission targets under perfect competition build upon the superior welfare effects of an arbitrary target.

2.4.5.2 Cournot Competition and Monopoly

When firms enjoy market power, optimal Design Standards can dominate. The result is closely tied to Proposition 2. The issue here is whether the optimal Emission Standard generates output below the social optimum after accounting for abatement costs. Welfare will be higher under Design Standards when the equilibrium market price is above marginal compliance costs. Further, the optimal Design Standard will become more stringent. These results are summarized in the following Proposition.

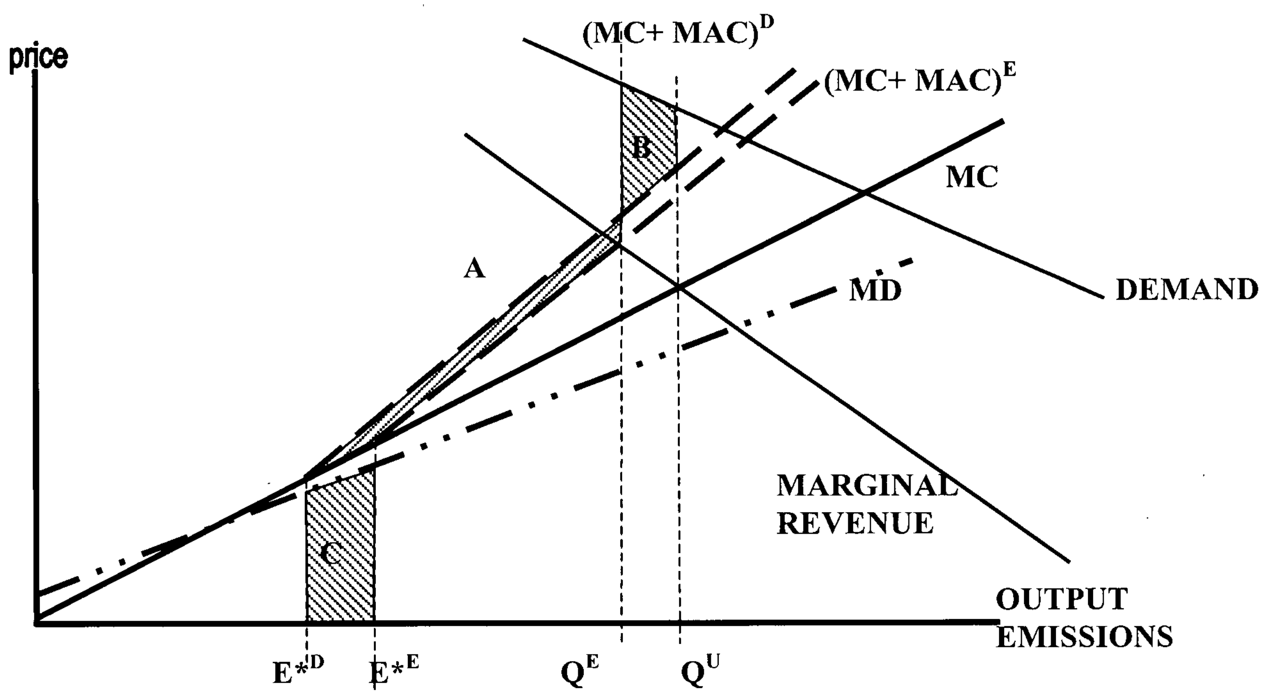
PROPOSITION 2.4: *Let* $N \geq 1$*., If* $MC^E(Q^U, E^{*E}) \leq P(Q^U)$*, then*

a) $E^{*E} \geq E^{*D}$ *and*

b) $W^{*D} \geq W^{*E}$

FIGURE 2.9 shows the comparisons under Monopoly using the same demand and costs structures as **FIGURE 2.8**. Imagine if the regulator were to impose the optimal Emission target using Design Standards. If we assume that marginal compliance costs of producing the unregulated market output and achieving the emission target ($MC^E(Q^U, E^{*E}) = [MC(Q^U) + MAC(Q^U(E^{*E}))]$) is less than the market price evaluated at the unregulated output $P(Q^U)$, then output under the optimal Emission Standard is below the social optimum. Proposition 2 establishes that Design Standards will be more efficient, given this target. It also means that the marginal costs to society, of restricting the target even further, is less under Design Standards than under Emission Standards. Hence the optimal Emission target becomes too slack under Design regulation. The regulator can restrict emissions, gain area C in FIGURE 2.9, and impose additional compliance costs of area A. This generates a net gain in addition to that of area B.

FIGURE 2.9: EMISSION versus DESIGN STANDARDS: MONOPOLY.



FIGURES 2.8 and **2.9** give us the limiting Cournot cases. We typically lie somewhere between these two extremes. Proposition 4 still holds: as long as the market price exceeds marginal compliance costs, Design Standards will dominate. However, as the number of firms rises, this becomes less likely. The market price will eventually fall below marginal compliance costs. Industry output will rise above the social optimum. This forces the regulator to relax Design Standards relative to Emission targets. As long as optimal targets differ by only a small amount, Design Standards can still dominate. There is a small band where the higher market output dominates the additional costs of compliance and slightly weaker targets. This is similar to the results in **FIGURE 2.7**. You can see, though, that as the number of firms rises we approach the competitive case where optimal Emission Targets dominate.

2.5: COST COMPLEMENTARITIES

The previous sections compare Emission and Design Standards under the assumption that abatement activities have no effect on production costs. Production and abatement are assumed independent. However, we would expect marginal costs to vary with abatement since the firm produces output and abatement jointly.[18] I now relax this assumption and show how some of the previous results change.

The imposition of binding regulations, now, has two effects on the firm's marginal compliance costs. The first, the direct effect, is that it forces the firm to take on additional inputs to meet regulations. This raises marginal costs. The change in abatement, though, indirectly affects C_q through the cross-partial effect. This effect can go either way. It can be positive or negative[19]. The question is whether marginal compliance costs rise or fall, on net, with regulation.

The possibility of cost complementarities implies that regulation can yield better market outcomes than an unregulated industry since it can increase the degree of competition. This lowers the output distortion. This benefit may be in addition to the benefits of reduced environmental damage and so constitute a "double dividend"[20]. In the absence of complementarities, regulation cannot improve market outcomes since regulated markets will not yield higher outputs. This pro-competitive effect may only be present under Design Standards (outlined below).

2.5.1 Cost Anti-Complementarities:

Lets first consider the case where a rise in abatement indirectly raises the firm's marginal costs[21]. For any *q* and *a* we must have $C_q(q,0) < C_q(q,a)$ if $C_{qa} > 0$.

[18] See Baumol, Panzer, and Willig (1982) for a thorough coverage of cost complementarities and joint production.

[19] The existence of cost complementarities is, of course, an empirical question. There is some support that they exist in some industries. Barbera and McConnell (1990) show that negative indirect effects can be found in some industries. The European Commission (1994) also found similar evidence.

[20] The "double dividend" was first used in the context of environmental taxes where tax revenues could be recycled to lower marginal rates on ordinary distortionary taxes. Under some circumstances, this could yield increases in social welfare in addition to reduced environmental damage. Hence the double dividend arises from the reduction in net distortions. See Goulder (2000) for a review.

[21] This cost anti-complementarity may arise from a need to increase the quality or quantity of inputs. For example, catalytic converters in cars require more expensive unleaded gasoline. Per kilometer costs rise for a given fuel efficiency,. This is often taken as a standard assumption. Besanko (1987), Barrett (1994), and Katsoulacos *et al* (1996) all use this to motivate why regulators would want to weaken emission targets. One needs to reduce targets, hence abatement, to raise competitiveness since this will lower marginal costs.

Cost anti-complementarities imply that marginal costs are always lower for unregulated firms. This holds regardless of the mode of regulation since the indirect effect is added to the direct effect. Cost anti-complementarities therefore worsen the competitive stance within industries by reducing each firm's ability to respond to their competitors.

For regulation Emission Standards this would be depicted as an increase in the slope of the marginal compliance curve. For a given target, firms will tend to restrict output even more than indicated in section 2.2.

For regulation under Design Standards, marginal compliance costs rise as do average costs. Output falls below the unregulated case though not as much as under Emission Standards.

The results given in Sections 2.2, 2.3, and 2.4 need some qualifications:

- Firms still prefer Emission Standards to Design Standards since output is more restricted and abatement costs are lower.
- The effect of binding Emission Standards on profits is ambiguous. As noted before, there are two effects on profits: the price effect and the cost effect. Both are stronger under cost anti-complementarities since the indirect effect reinforces the direct effect on marginal costs. However, the stronger the direct effect, relative to the indirect effect, the more likely regulation will raise profits since the indirect effect imposes a relatively large cost effect (as it raises infra-marginal costs).
- Design Standards will still lower profits since average costs rise more than marginal costs.
- Proposition 2.2 (Necessary Condition for Design to dominate Emission Standards) still holds.
- The existence of anti-complementarities will tend to increase the likelihood that Design Standards dominate Emission Standards in the presence of market power. The issue is that the indirect effect of regulation will tend to restrict output more under Design Standards than under Emission Standards. This follows since the indirect effect on marginal compliance costs, as a fraction of total marginal compliance costs, is larger for Design Standards (recall: the direct effect is absent under Design Standards). This implies that the indirect effect on output is stronger. Hence output, under Design Standards, is more likely to fall below the social optimum. This would then imply, by Proposition 2.2, that Design Standards dominate.

2.5.2 Cost Complementarities:

Consider, on the other hand, the case where a rise in abatement indirectly reduces marginal costs[22]. The firm's cost structure rises (i.e. it has higher average costs everywhere) but its slope may fall. The net effect on marginal compliance costs is ambiguous and depends on the mode of regulation and on the strength of the complementarity. The following proposition establishes that, under cost complementarities, the marginal compliance costs of a regulated firm can fall below that of unregulated firm for a given output and a given emission target. Note that the rise in average costs implies that the firm will choose the least amount of abatement permissible.

PROPOSITION 2.5: *Let emission targets be binding and* $C_{qa}<0$*. Then:*

(a) (Design Standards) $C_q^D(q,a) < C_q^U(q,0)$*, and*

(b) (Emission Standards): $C_q^E(q,a) < C_q^U(q,0)$ *if* $C_{qa}(q,a) << 0$*.*

The idea behind Proposition 5 is simple. Consider Design Standards first. The regulator imposes an abatement target for the firm. The direct effect on marginal costs is absent while the indirect effect is negative. This lowers marginal costs below those of unregulated firms.

Now consider Emission Standards. The regulator imposes a particular emission target for the firm. Suppose the firm reduces output to comply with the target and then considers raising output. As it raises output it must also raise abatement. This direct effect is positive. The indirect effect of the higher abatement is to lower inputs used in production. It is possible for the indirect effect to dominate the direct effect. This only occurs however if

[22] Barnett (1980) noted this possibility but dismissed it as unlikely. These cost complementarities may arise in a number of different ways. For instance, firms may be able to use recycled effluent in their production process. This reduces their requirement for virgin inputs and so reduces marginal costs. Alternately, firms may be able to sell effluent and so recoup some production costs. Golombek and Raknerud (1997) report how a Norwegian Pulp and Paper company has used its *lignin* effluent to become the world's largest vanillin manufacturer. It also uses its *hemicellulose* effluent for ethanol production. Manure from dairy operations, sulfuric acid from scrubbers, or wood chips from mills are also possible examples. A third mechanism is when firms alter their production processes to meet their emission targets. These changes in production, say by increasing energy efficiency, or substituting cleaner inputs, can lower marginal costs despite raising average costs. A forth source, outlined by Baumol, Panzer, and Willig (1982), is the existence of public inputs (p. 75). These are inputs that, when used for one production process, are freely available for other processes. For example, monitoring the quantity and quality of effluent can give plant managers information about the efficiency of production and so allow them to adjust production to maintain peak efficiency. An example of this is the AirCare program in British Columbia. Cars' exhaust is tested and, if in non-compliance with regulations, owners are required to undertake repairs that can raise fuel efficiency. Porter and van der Linde (2000) give other examples.

the cost complementarity is sufficiently strong. If it is weak, then marginal compliance costs will rise with regulation.

In either case, output rises above that in the absence of the positive cost complementarity.

By assumption, total costs rise with regulation otherwise firms would unilaterally adopt abatement. This implies that the social optimum, given a particular target, lies below the unregulated output. Output under Design Standards lies above the unregulated output an above the social optimum. Output under Emission Standards can be above or below either the social optimum or the unregulated case. This suggests that, as in the cost anti-complementary case, the results from before are left relatively intact:

- Profitability under Emission Standards is lower. Although infra-marginal costs fall total costs rise for a given output and target. This lowers profits. Output also rises so lowers profits even more.
- Design Standards are even more inimical to profits since regulations push output above the unregulated market.
- Instrument choice is biased away from Design Standards and towards Emission Standards. Here, the indirect effect lowers marginal compliance costs relatively more under Design Standards so has a larger output promotion effect. This will tend to push output (further) above the social optimum and so bias the regulator toward Emission targets.
- As before, once the number of firms rises significantly, or if marginal compliance costs are high, or if emission targets are stringent, then the flexibility of Emission Standards becomes paramount as the output promoting effect is less important than the cost savings.

2.5.3 Double-Dividend under Cost Complementarities

The existence of cost complementarities implies that a regulated industry can be more competitive than an unregulated industry. This is contrary to standard intuition and is consistent with Porter's (1990) hypothesis. His idea was that regulations would induce firms to innovate and so, over time, reduce their cost structure[23]. This makes them more competitive and more profitable[24]. Innovation is conceived primarily as process innovation.

[23] See Simpson and Bradford (1996) for a cogent critique and analysis of this claim.
[24] See Porter and van der Linde (2000) for case studies where this occurred.

Innovation in input use and marketing of recyclables are also important (Porter and van der Linde , 2000). Porter's proposition was explicitly a dynamic effect. The pro-competitive aspect noted here, rather, is entirely static but captures some of the same idea. Note that the effect here also differs from Porter's hypothesis in that firms become less profitable though more competitive. Profits tend to be lower with regulation[25].

The pro-competitive effect under cost complementarities means that regulation can diminish pollution levels while also raising output. The question I now turn to is whether the regulator can exploit this output effect and raise social surplus. This would require that the rise in output more than cover the increase in compliance costs. I first show that the double-dividend can only occur in the presence of market power and is more probable under Design Standards. I then ask whether it can occur under perfect competition. I show that it cannot.

2.5.3.1 Double-Dividend under Monopoly or Cournot Competition

First consider a monopoly regulated under Emission Standards. We can think of two scenarios: a strong and a weak complementarity effect. Assume that the complementarity is weak so that the direct effect dominates. Output falls as does social surplus and there can be no double-dividend. If, on the other hand, the complementarity is strong enough, then marginal compliance costs under Emission Standards fall below the unregulated firm. That is, the direct effect is dominated by the indirect productivity effect. This raises output and admits the possibility of a double-dividend.

Recall that in a monopoly, without regulation, the equilibrium output is inefficient since there is too little production. With regulation and strong complementarities, however, the firm rationally raises output. Hence, there is no necessary tension between choosing stronger regulation and raising the output distortion; regulation can decrease the output distortion while simultaneously reducing pollution[26]. Can regulation decrease the output distortion enough to cover additional costs? Yes, it can.

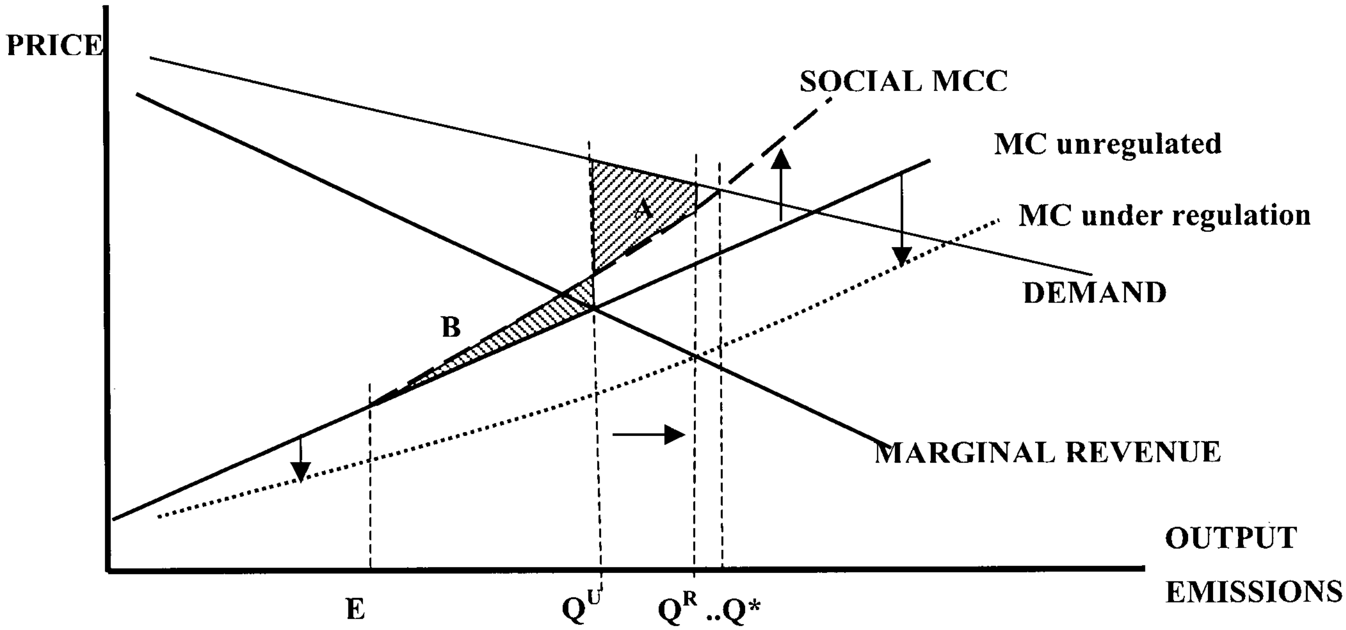
To see this, consider **FIGURE 2.10**. The unregulated firm produces at Q^U. If required to attain target E, the firm's private marginal compliance costs fall in the relevant

[25] This is consistent with a weak form of the Porter hypothesis. This weak form says that firms become more competitive but the cost of acquiring new technologies is not fully offset by reductions in production costs. The strong form says investment costs are fully recovered (Simpson and Bradford, 1996).

[26] This is exactly opposite to the story given by Katsoulacos *et al* (1996) and Barnett (1980). In their case, the optimal emission target will be more stringent, all things equal, than a Pigouvian type rule.

range of output. The firm raises production to Q^R where R refers to the regulated monopolist.

FIGURE 2.10: DOUBLE DIVIDEND under MONOPOLY



Total costs however rise. If they did not, firms would unilaterally abate and regulation would not be needed. I am assuming that regulation is needed to induce abatement. That means we have to differentiate between the increase in marginal costs taken from the firm's point of view and from the regulator's. Despite the complementarity, the social marginal compliance cost (SMCC) is strictly higher than the unregulated firms' marginal costs. The firm has social marginal compliance costs of $C^S{}_q(Q^U,A)$. This is higher than unregulated marginal costs of $C^U{}_q(Q^U,0)$. Assume now that the market price is everywhere above social marginal compliance costs in the relevant range of output. It need not be. Area A in **FIGURE 2.10** is the output effect (the net gain in Social Surplus of moving from Q^U to Q^R and accounting for the increased abatement costs). Area B is the cost effect (the loss in Producer Surplus of attaining the target E and maintaining output at Q^U). As long as area B is smaller than A, social surplus rises with regulation. This gives us the double dividend.

Three factors matter in determining whether the double-dividend exist. First are social marginal costs. The higher this is, the more regulations raise area B, and the smaller the net benefit of regulation. This would be the case if abatement were difficult to achieve.

Second is the strength of the output effect. With Design Standards, the output promoting effect is stronger so can yield even more net social benefits. The regulator would want to use Design Standards as long as the conditions for Proposition 2 held. If cost complementarities are weak, then the output effect is also weak. For instance, under Emission Standards, regulations would reduce output. The double-dividend disappears regardless of how much market power the firm has. With Design Standards, output rises and so the possibility of capturing the double-dividend still exists. Hence the double-dividend becomes a *function of* the mode of regulation.

Third is the size of the output distortion. If this is small, then the rise in output offers few benefits. I show this under perfect competition.

2.5.3.2 Double Dividend under Perfect Competition

Can regulation generate a double-divided under perfect competition? The answer is no, it cannot. The reason is that regulation increases the costs to firms more than it increases benefits consumers. Hence social surplus falls.

To see this recall that regulations raise firm's average costs under Emission Standards. In perfect competition, firms end up producing where their marginal compliance costs equal the market price. That price however is less than the social marginal compliance cost and so output is too high. The gain in Consumer Surplus is totally offset by the higher production costs. In FIGURE 2.10, the value of area A, which is the benefit of more output, is negative since it is to the right of the social optimum. This negative benefit is added to the costs in area B. The net effect is unambiguously negative.

Do Design Standards do any better? Again, the answer is no. Proposition 3 tells us that output under Design Standards is too high and so lowers the surplus relative to the Emission Standard. By transitivity, Design Standards lower social surplus below that of unregulated markets.

We can conclude that, in Perfect Competition, environmental regulation *cannot* raise Social Surplus: there can be no double-dividend. The double-dividend is *only possible* when the market is producing below the social optimum: market power becomes a necessary condition.

Market power is not sufficient since there may be a limit to how much you can capture social surplus by reducing emissions. The issue is whether the increase in production justifies the additional compliance costs. This is the similar to the problem of choosing the efficient instrument in Section 2.4. This should not come as a surprise given what we know about second-best policies. One needs a pre-existing distortion to justify the introduction of another. Under perfect competition, the only distortion was due to the pollution damage firms inflicted on the environment. *If* we chose to ignore that damage, then the market is function properly and there is no scope to introduce another distortion. With market power, there is a distortion, so regulation can generate benefits in addition to reduced pollution damages. This is exactly the idea behind the double-dividend.

Regardless of whether a double dividend exists, the presence of cost complementarities does reduce the social cost of regulation and will tend to facilitate stricter environmental policies. This has specific policy implications. It suggests that the development new abatement technologies and of markets for treated and untreated effluent can be a productive, and ultimately environmentally sound, strategy for governments to employ. They reduce the direct cost of regulation.

2.6: CONCENTRATION STANDARDS

The focus so far has been on comparing Emission and Design regulations. These are not the only modes of environmental control. An important alternative is the Concentration Standard where the regulator specifies the pollution intensity of the firm's output rather than the firm's level of emissions. As noted in the introduction, this is often the most common form of regulation. The intent is to limit exposure over specific periods of time giving the environment time to absorb and naturally abate pollution. As with Design Standards, the regulator does not directly limit emissions so must compute the regulation criteria so as to achieve the target indirectly. However, like Emission Standards, abatement must change with output to comply with regulations. I assume that the Concentration Standard is chosen so as to attain the same target as a Emission regulation. This makes the three regulations directly comparable.

Let us return to the original problem facing the firm but with this new regulation. From here on, I again assume that the firms' costs are separable. I do this for simplicity only. The results that follow can be extended to include complementarities.

The j th firm's maximization problem can be written as:

$\mathbf{Max}_{qa}\ \pi^j(q_j, a_j, q_{-j}) = R(q_j, q_{-j}) - C(q_j) - D(a_j)$ Subject to: $e^j(q_j,a_j) / q_j \leq K$ where K is chosen by the regulator to achieve an emission target E. The first order conditions for an interior solution yields:

$$\textbf{(K)}\qquad R_q = C_q(q) - D_a\,[e_q(q,a) / e_a(q,a)] + K\,[C_a(q,a)/e_a(q,a)] := C_q^{K}(q,a).$$

Rather than go through all the details as in Sections 2.2 to 2.4 I summarize the results in the following Proposition. They show that Concentration Standards are placed between Emission and Design Standards in terms of output, abatement costs, profits, and welfare. Further, as long as the social marginal compliance cost of achieving a particular target is less than the market price, Concentration Standards dominate Emission Standards. This is similar to Design Standards. Proposition 2.6 is the analog to Propositions 2.2, 2.3 and 2.4.

PROPOSITION 2.6: *Suppose we have $N \geq 1$ and $C(q,a) = C(q) + D(a)$. For an arbitrary target we have:*

a) *Output:* $Q^E \leq Q^K \leq Q^D$,

b) *Abatement:* $A^E \geq A^K \geq A^D$, *and*

c) *Profit:* $\Pi^E \geq \Pi^K \geq \Pi^D$.

d) *Welfare:* $W^K \geq W^e$ *when* $P > C_q^K(q,a)$.

e) *At the optimal target we have:* $W^K \geq W^E$ *and* $E^K \leq E^E$ *when* $P > C_q^K(q,a)$.

The intuition behind Proposition 2.6 is relatively simple. The interpretation of the first order condition (K) is similar to that for the Emission Standard since it is really just another kind of performance criterion. Both permit the firm to adjust output and abatement to maintain compliance. They differ in effect. Under a binding Emission Standard, a rise in output requires a rise in abatement. Under the Concentration Standard, however, a rise in output entails a smaller rise in abatement. The firm does not have to preserve the *level* of emissions; it just maintains the *ratio* of emissions to output. This is less than one-to-one. Hence, the Concentration Standard yields lower marginal compliance costs at high output levels. This is easily seen since, if both constraints bind, the first two terms in (K) and (E) are the same, but the third term in (K) is negative.

Notice also that marginal compliance costs are everywhere higher compared to the unregulated firm since abatement is always required regardless of output. This is similar, though not necessarily the same, as imposing emission charges and will show up in the determination of profits.[27] This increase in marginal costs along the entire range of output means that each firm's reaction function shifts in. The effect is that output falls from the unregulated equilibrium (and compared to Design Standards) but not as much as under Emission Standards. Abatement, given the same emission target, is higher than that under Emission Standards.

Profits (typically) fall under Concentration Standards despite the restricted output. This differs from Emission Standards as profits there can rise. The difference lies in the infra-marginal effects on marginal compliance costs of imposing the concentration criterion. Marginal compliance costs are everywhere above those of the unregulated firm. Under most demand conditions, this shift up of the entire marginal cost schedule cannot yield better outcomes for firms. In essence, the rise in the firms' average costs is proportionately more than the rise in equilibrium prices. This reduces the average markup and, since output is lower, reduces profits. This is exactly the same effect as a non-rebated emission charge: prices rise, markups fall, and so do profits. Profits, however, remain higher than that under Design Standards. This follows from the fact that equilibrium output and abatement under Design Standards meet the Concentration criterion.

As with Design Standards, we can infer the social marginal costs of an emission target by looking at the marginal compliance costs under Emission Standards for the equilibrium output under (K). As in Proposition 2.2, the critical point is whether the equilibrium price exceeds the marginal compliance cost. Alternately, it is whether equilibrium output is below the social optimum, inclusive of abatement costs. If this holds, then Concentration Standards dominate Emission Standards for either an arbitrary target or for optimal targets.

Design Standards, however, may dominate Concentration Standards. For example, if the conditions for Propositions 2.2, 2.3, and 2.4 hold, then the relationship between Design

[27] This would also be similar to a Design Constraint that forced firms to adopt a particular abatement process that increased variable, hence marginal, costs.

and Emission Standards holds for Design and Concentration Standards. Design Standards raise output but not above the social optimum. Hence under Proposition 2.2, Design dominates both forms of performance regulation.

Together, this means that the range of values over which Emission Standards, and by extension tax based measures, are efficient is smaller than indicated in FIGURE 2.7. There will be a range (not shown) where Concentration Standards dominate the other two, reducing the ranges of dominance for both.

2.7 OUTPUT CONSTRAINTS

In this section I consider another form of regulation. I look at the equilibrium effects of output constraints as a form of environmental regulation and compare them to the previous types of regulation. Here, the regulator stipulates the maximal output for a firm but does not require any further abatement activities. For output less than the target, output is unconstrained and so marginal costs are the same as an unregulated firm. Once output reaches the constraint, implicit marginal costs become infinitely large. The firm does not abate at any time. This regulation seems pertinent in situations where abatement costs are prohibitively high or when there are no abatement possibilities available to the firm other than reducing the scale of operation. For instance, industrial activity in ecologically sensitive or pristine areas creates damage by its very existence and so the only way to reduce damage is to reduce the level of activity. This is essentially the framework for our National Park systems: we limit economic activity precisely because we want to maintain some level of pristine wilderness. Another example would be the letting of logging permits where the government takes over the responsibility of reforestation financed through license fees. Firms log up to their permits but do not otherwise abate.

To make all regulations directly comparable, I assume abatement is possible but the maximum output level will be chosen so that emissions will not exceed E with zero abatement.

The consequence of the output constraint is to exaggerate the effects of the Emission Standard since it raises marginal costs even more[28]. Comparing Output regulation directly to

[28] Alternately, when abatement is not possible, a emission constraint is a *de facto* output constraint. Ulph (1992) takes this approach.

the other standards yields the following results (using P, K, D, O to refer to Emission, Concentration, Design, and Output regulations respectively):

PROPOSITION 2.7: *Suppose we have $N \geq 1$ and $C(q,a) = C(q) + D(a)$. For an arbitrary target we have:*

e) *Output:* $Q^O \leq Q^E \leq Q^K \leq Q^D$,

f) *Abatement:* $A^E \geq A^K \geq A^D \geq A^O = 0$, *and*

g) *Profit:* *n small:* $\Pi^E \geq \Pi^O$

N large: $\Pi^O > \Pi^E$

h) *Welfare:* $W^E \geq W^O$

e) *At the optimal targets we have:* $W^E \geq W^O$ *and* $E^E \leq E^O$

The output and abatement effects are straightforward and need no explanation. Profits are a little more complicated since they can rise under regulation. I turn to these.

Under monopoly, Output constraints yield the lowest profits. Emission Standards, of course, offer the highest profits since they accord the firm the most flexibility. The firm can choose to, but need not, attain any of the other constraints hence cannot do worse. Profits under Design Standards may be higher or lower than that of Output Standards. *A priori* we cannot say which is higher since neither generates outcomes that satisfy both sets of constraints. However, abatement costs, as a fraction of total costs, do not appear to be high in practice so it seems reasonable to assume that the benefit of increased output afforded under the Design Standard more than covers any additional abatement costs. Hence we can assume that profits are higher under Design Standards.

With more than one firm, the effect on firms' profitability within standards, and in comparison to an unregulated case, is quite different from the monopoly case. The issue here is that firms compete head to head. Regulations will change the degree of competition between firms, reduce competition, and yield benefits to firms.

First, consider the case of perfect competition and compare Output to Emission Standards. Suppose first that demand is perfectly elastic. A binding Output Standard reduces output more than the corresponding Emission Standard. Since the restriction in output has no price effect, the firm is strictly worse off than firms under Emission constraints. As demand elasticity falls, the restricted output generates higher prices. If the

Output Constraint puts industry output above the joint profit maximizing level (where industry marginal revenue equals marginal costs), then the Output Standard yields higher profits than those under Emission Standards.

This is also true in the Cournot case where firms compete directly. Output Standards force each firm to restrict its own output to some extent. Firms would like to do this but, if unconstrained, are not able to credibly commit to lower output levels. Each has an incentive to expand output. They cannot do so under the Output Standard. As long as the target is not too low, the combined output of all firms will be closer to the output of an unregulated monopolist. Hence joint profits are higher. Under the other standards, output is too high from their collective standpoint. Firms are competing too vigorously.

Compared to unregulated firms, Output regulation raises profits as long as market demand elasticity is not too high and the emission target is not too strict. This follows since a binding output quota forces each firm to produces less than unregulated firms. With a downward sloping market demand curve, unregulated firms over compete and so dissipate rents. Profits rise under Output Standards since regulations rein in that competition without forcing firms to abate. They like this as long as the emission target is not too stringent so as to reduce industry output far below the joint profit maximizing level.

The welfare effects of Output constraints are unambiguously worse than Emission Standards regardless of demand, production costs, or abatement technologies. This is true for arbitrary and optimal targets. Consider arbitrary targets first. One way to envision the superiority of Emission Standards is to imagine that marginal abatement costs (MAC) are infinitely high. Hence an Emission constraint is effectively an Output constraint since firms unilaterally choose not to abate. All "abatement" is in reduced output. Now imagine a new abatement technology that lowers MAC. This will allow firms to raise output and abatement while maintaining emissions. Is this better for society? Clearly it is since the market price, regardless of the number of firms in the industry, never falls below the firms' marginal compliance costs. Hence, the rise in output creates a net social benefit and Emission Standards cannot do worse than Output constraints. Since Emission Standards do better for arbitrary targets, they must do better at the optimal Output target, and so cannot do worse when they are optimally chosen.[29]

[29] Note that under cost-complementarities, output constraints may be preferred to Emission Standards. The issue arises when output, under Emission Standards, exceeds the social optimum as would happen under perfect

The optimally set Output constraint will exceed the optimally set Emission target as long as marginal damages are increasing in emissions and the wedge between market price and marginal production costs declines with output. Hence optimal Output constraints will be too slack.

Output Standards can dominate Design Standards. A necessary, though not sufficient, condition is that equilibrium output under Design Standards exceeds the social optimum.

2.8: CONCLUDING REMARKS

The prime insight offered here confirms that firms and regulators need to concern themselves as much with the mode of regulation used to achieve targets as with the targets themselves. I compare different Command and Control regulations within a simple graphical framework that highlights the different output effects each generates. These instruments are not equivalent as they affect firms quite differently.

It is well known that, in this static framework, emission taxes can be made equivalent to Emission Standards. This is made clear in the firm's problem in Section 2.2. What I show is that firms may prefer Command and Control regulations more than incentive-based regulation and may not be entirely obverse to all forms of regulation. Further I show how Command and Control regulations can perform better than Emission Standards and hence better than incentive-based regulation. Let me discuss each in turn.

All forms of Command and Control instruments tended to reduce competition in this model. Only Design Standards do not. Output Constraints restrict competition the most while Emission constraints are equivalent to emission taxes. As a consequence of this reduced competition, Output and Emission regulations can increase firm profitability above that of unregulated firms. These forms of regulations may not be entirely opposed by industry. Firms, on the other hand, will tend to oppose Design and Concentration Standards since these tend to decrease profitability. This was also true for emission charges unless lump sum rebates are given to firms.

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competition. The problem is whether the social cost of excess production is worse than the social cost of too little production. There are no necessary or sufficient conditions for this to hold. It would depend on how strong the output constraint needs to be to achieve the target, how fast marginal abatement costs rises, and how strong the cost-complementarity is.

Although firms will oppose Design and Concentration Standards, their maintenance of industry competition can make them efficient instrument choices in some circumstances. I show sufficient conditions for this to hold. This relies critically on output effects. One way to understand this is to consider the nature of the regulator's second-best problem and imagine she implements the target using a combination of emission taxes and output subsidies/taxes. The regulator wants to reduce emissions but is concerned with the reduction in output that this entails. The first-best solution, of course, is to tax emissions and offer an output subsidy to raise production to the social optimum. In some sense, Design Standards can do this but in a rather ham-fisted way. A regulator can replicate the Design Standard with appropriately set emission taxes and a fully offsetting output subsidy. The firm will respond to the emission tax by abating and to the output subsidy by maintaining output. This fully offsetting subsidy will only equal the optimal subsidy by happenstance. Output will generally be too low or too high (where high or low is relative to where the social marginal compliance cost crosses the demand curve). However, as long as the output subsidy remains too low, then the subsidy is a strict (Potential) Pareto Improvement. Hence a Design Standard that attains the same target as an Emission Standard (which has no implicit subsidy) can perform better. Note further that an abatement subsidy will encourage the firm to reduce emissions and have little, or no, output promoting effects. Consequently, abatement subsidies can also be an effective tool in the regulator's arsenal given the problem of too little production.

If the subsidy is "too large" then it can worsen outcomes. This was the case under Perfect Competition where Design Standards are not efficient.

Concentration Standards can also be replicated with an emission tax and output subsidy. The equivalent subsidy is smaller than that under Design Standards. Hence it does better only when Design Standards have too high of an equivalent subsidy.

Output Standards can be replicated with a simple output tax. But output is too low, so this seems the worst possible strategy.

Some disclaimers are in order. First, the attractiveness of Design Standards over Emission constraints derives fundamentally from the assumed fixed cost nature of the Design Constraint used in this Chapter. One could imagine, on the other hand, that the Design Constraint forces firms to engage in particular processes that are tied to the level of production. Hence all costs would be variable costs. Further, as Kalt (1985) and Porter *et al* (2000) suggest, these imposed processes need not be the most technically efficient. The effect an marginal compliance costs, however, will be very much like that for Concentration Standards: the schedule of marginal costs rise throughout the range of production but do not rise as high as those under Emission Standards since there is no explicit limit to emissions. The results reported here become somewhat more complicated. The main result that Design Standards can offer a Potential Pareto Improvement over Emission Standards, however, survives. As do the effects on firm profits.

Second, the lack of entry and exit possibilities will affect these results as well. However, to the extent that free entry leads to excessive entry, Design Standards offer the regulator a lever that simultaneously reduces emissions and, like permits, reduces the number of firms in the industry. This simultaneously corrects the two market distortions in addition to the externality. Emission constraints may also lead firms to exit but that pressure will be more muted. The net effect may be to increase the range over which Design Standards dominate Emission Constraints.

Third, I am not necessarily advocating the use of Design Standards over Incentive Based instruments. I am suggesting that there are benefits to traditional Command and Control instruments that have not been previously appreciated.

Forth, the regulator used in this Chapter is a passive automaton that simply sums consumer and producer surpluses and chooses the target and instrument from these sums. Actual choice of instruments is likely to involve a much more complicated interaction between affected parties. The analysis here sheds some light on the potential winners and losers as well as possible coalitions that may form. As such, it offers the first step in a larger analytical problem.

CHAPTER 3: ENVIRONMENTAL DESIGN AND THE RACE TO THE BOTTOM

3.1 INTRODUCTION:

> It is worth noting that environmental management is not just a question of deciding upon the upper level of pollution that should be allowed, but is also a question of the policy measures chosen to keep the pollution below this level.
>
> (Hansson, 1990, p. 105)

This chapter analyzes how a country's choice of regulatory *regime* influences the *level* of environmental protection chosen in an open economy when governments care about the competitiveness of their industries. The motivation for this analysis comes from two different, but related, concerns. First, there is apprehension among many environmentalists that industrial interests have come to dominate environmental interests. In particular, they fear a "race to the bottom" where nationalistic governments subsidize local production through weaker standards and leave domestic industries unregulated.[1] Barrett (1994), among others, shows that this concern is justified. He confirms that countries indeed may have an incentive to strategically lower environmental quality for commercial gain. The second concern is among economists who argue for changes in the <u>way</u> firms are regulated. Most current environmental regulation is of the Command and Control sort (Dewees 1983, Helfand 1991, Potier 1997). The claim is that current environmental policies are incompatible with maintaining international competitiveness. Kalt (1985), for instance, argues that over-reliance on these traditional, quantitative restrictions has increased the costs to American firms significantly above that which would obtain under more efficient, incentive-based instruments. He claims that these excessive costs have impaired American international competitiveness.[2] Kalt calls for the use of more incentive-based regulations. This would facilitate increased competitiveness for a given environmental quality. Alternatively, it might open the way for more stringent environmental policies. Esty (1994) puts it in the following way:

> Movement away from technological standards toward market-based, performance-oriented environmental regulation can improve the efficiency of environmental regulation and help the public get the maximum bang for its

[1] A weaker form would be a "race towards the bottom" where firms are regulated but less than under a first-best rule.

[2] Jaffe, Peterson, Portney, and Stavins (1995), on the other hand, find little evidence suggesting significant effects on competitiveness. They attribute this, in part, to relatively low compliance costs and similar regulatory costs across competitor countries.

> environmental buck and, at the same time, narrow the scope for conflict between trade liberalization and environmental protection. (p. 17)

Esty's concern is that increased interdependence of national economies weakens governments' ability to manage their domestic environment and simultaneously maintain a free and open trading system. This either weakens their commitment to a cleaner environment or to freer trade.[3] Anderson and Blackhurst (1995) make the comparable claim that "the lower the cost of protecting and improving the environment, the larger will be both the degree of public support across countries and the amount of environmental improvement accomplished" (p. 5). The suggestion, then, is that more efficient regulation can accomplish two goals: a cleaner environment and more competitive industries.

The purpose of this chapter is to evaluate this claim. The principal question asked is whether more "efficient" modes of regulations allow countries to attain higher environmental quality while enhancing international competitiveness. An efficient regulation is defined here, as does Kalt, as one that minimizes the cost of achieving a particular environmental target.[4] The focus of the Chapter is how a country's choice of *regulatory regime* influences the *level* of environmental protection in an open economy when governments care about the competitiveness of their industries. In particular, I ask whether these more efficient regulations decrease the risk of a "race to the bottom". To do this, I compare Emission Standards (i.e. non-tradable emission quotas), and Emission Charges, against technical Design Standards.[5] Design Standards are chosen as a representation of current "inefficient" regulation as they are not the least cost mode of achieving targets (Besanko 1987). Both Emission Standards and Emission Charges give the firm full flexibility so ensure firms attain their emission targets at least cost.[6]

The primary result is that the linkage between competitiveness and environmental stringency is a *function of* the regulatory regime employed. Further, governments need to be

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[3] A decoupling of the two spheres, of course, would allow countries to pursue trade policy independent of environmental policy. This decoupling may be difficult to attain.

[4] This may be different from one that maximizes social welfare. As is well established, inefficient regulation, in a second-best world, can yield higher payoffs.

[5] In the model used here, non-strategic emission charges are equivalent to Emission Standards. The two differ only when countries behave strategically. See Ulph(1992) for a discussion. Though not fully equivalent to Emission Standards, Emission Charges do have similar strategic effects. I leave it to later research to compare Emission Standards and Emission Charges directly.

[6] Emission Standards may not be efficient when domestic firms differ in their abatement costs. The problem is that the distribution of emission permits might be inefficient. I abstract from this heterogeneity by assuming a single domestic firm.

concerned that introducing "efficient" regulations also introduces pressure to weaken targets that may not have been present in current regulations. This tempers Esty's claim. I show that the use of Emission Standards and Emission Charges creates a direct link between the international competitiveness of a nation's industries and the stringency of its environmental targets. This can lead to lower, rather than higher, environmental quality. It also permits the possibility of an extreme "race to the bottom" where firms are, effectively, unregulated. This could be through non-binding emission targets or marginal emission taxes of zero.

In contrast, I show that the traditional Command and Control regulatory structure, characterized by Design Standards, can de-link environmental stringency from firm competitiveness. This, in turn, can eliminate the possibility of a "race to the bottom" in that country. Targets are always set so that marginal damages equal marginal abatement costs. This condition holds regardless of the type or stringency of foreign regulations. The linkage between domestic competitiveness and environmental stringency is completely severed. The difference between the policies lies in how the regulatory regime affects firm's marginal costs and their reaction functions. This, in turn, determines the extent to which governments can use environmental policy as industrial policy. Design Standards differ from the other regulations since they do not alter firm's marginal costs though they do raise average costs. Emission taxes and Emission Standards raise marginal costs, shift in reaction functions, and so provide an incentive for governments to reduce targets.

The likelihood of a race to the bottom appears strongest under Emission Charges. It is less likely under Emission Standards. It is also more likely if competitor nations remain unregulated or if they use Design Standards. The race to the bottom, though, is by no means a certainty. It depends on the elasticity of demand, marginal damages, and marginal abatement costs. The greater the demand elasticity, the more likely the race since small changes in marginal costs can generate large changes in market share. On the other hand, we would not expect a race if pollution were highly toxic. The damage of raising emissions dominates any gain from increased market share. Similarly, high marginal abatement costs reduce the probability of a race under Emission Standards. In effect, high marginal abatement costs reduce firms' ability to react to market conditions so removes the regulators' incentive to manipulate targets. Regulators would unilaterally choose a binding target. This is not true with Emission Taxes. Here, imposing a small, unilateral tax, given high marginal abatement costs, means that firms will reduce output rather than raise abatement. The loss in market share dominates the gain in environmental quality and so eliminates any unilateral incentive to reduce emissions.

More importantly from a policy standpoint, when a race to the bottom is likely, or if the foreign industry is completely unregulated, Design Standards become a (weakly) dominant strategy over Emission Standards or Emission Charges. This means that countries need never be forced into any race. In effect, the choice of Design Standards commits the regulator to a form of non-intervention. Given that countries compete with targets, this commitment to non-intervention has positive payoffs in some circumstances.[7]

The capacity of Design Standards to dominate the other two regulatory approaches is a strong result. Emission Standards, that are determined without regard to the effect they have on the foreign firm (i.e. are set non-strategically), always dominate Design Standards. It is only the presence of the strategic incentive to manipulate targets that makes Emission Standards unattractive. The same holds for Emission Charges. Esty's claim therefore that more efficient regulations are to be preferred holds *only if* targets are chosen non-strategically. Cost-minimizing regulations, in the face of strategic considerations, might not offer the expected gains.

The model used to generate these is a variant of Brander and Spencer's (1985) rent extraction model employed by Barrett (1994), Ulph (1992, 1994, 1996), Verdier (1992) and found in Brander (1995). This model is chosen since it illustrates, quite clearly, the pure motive to manipulate emission targets while allowing comparisons across different regulatory regimes. I differ from Ulph and Verdier in that the emission target is endogenous and from Barrett in that there are alternative instrument choices available. In particular, I show how Design Standards and Emission Charges contrast with the Emission Standards used by Barrett.

There are three types of agents: Governments that choose the type of instrument, Regulators that determine the optimal emission target, and Firms that produce a homogeneous output and compete in Cournot fashion on world markets. Countries are in all ways identical. Interaction between governments, and between governments and firms, is modeled as a Three-Stage Game. Cooper and Reizman (1989), Hwang and Schulman

[7] See Hwang and Schulman (1993) for treatment of non-intervention in the context of strategic trade policy.

(1993), and Shivakumar (1993) use this type of model. With theirs, governments choose optimal trade policies in a strategic setting.[8] Ulph also uses a Three-Stage model although the regulatory mode is exogenous. The three stages are:

Stage One: Each Government, Home (H) and Foreign (F), chooses Design Standards (D), Emission Standards (E), or Emission Taxes as a mode of regulation taking the other Government's choice as given. Their objective is to choose the instrument that maximizes the sum of rents less pollution damage.

Stage Two: A Regulator in each country, given the regulatory instruments chosen by their respective Governments, decides on the optimal domestic emission target by balancing pollution damage and rent extraction.

Stage Three: A single profit-maximizing firm in each country engages in a polluting activity. Pollution is purely local. Their output and abatement choices are made given the domestic emission target and regulatory instrument and given foreign output. Each competes in Cournot fashion in world markets.

First, it is important to note that there is no domestic consumption. Production is for export only. This focus on exports only, as Brander (1995) argues, isolates the pure strategic motive to manipulate policies (p. 1405).[9] Clearly, the existence of domestic consumption would alter results. However, this alternative is best left to a mutual dumping model (also found in Brander, 1995). I leave this to future research.

Second, there is no entry or exit so the number of firms is fixed at one. Allowing entry is likely to alter the strategic incentive to manipulate targets. I leave to future research how this plays out.

As is standard, we first solve the Third Stage by finding each firm's reaction functions to rival output under each instrument and target. We then proceed through stages

[8] As Hwang and Schulman (1993) argue, this differs substantially from a Two-Stage Game in which the instrument choice and level are simultaneously determined. They considered an optimal tariff problem with strategic interaction. There, the government can choose non-intervention in markets as a policy choice. This, of course, is not the same as choosing an optimal zero tariff.

[9] Capital is assumed immobile so firm locations are fixed. This simplifies the analysis by excluding discontinuities in the regulator's choice of targets while still capturing the incentive to manipulate targets. See also Markusen, Morey, and Olewiler (1995) for a model of endogenous plant location. See also John Wilson (1996) for good review of the firm location problem under environmental regulation. Note that the locational decision will also be a function of the regulatory regime. This aspect has not been explored to my knowledge.

Two then One. Stage One and Two capture the idea that legislation is often in place that spells out *how* targets are to be achieved prior to the determination of those targets.[10] Targets are then determined within some social decision process. The First Stage provides governments with an opportunity to harmonize instruments while allowing local environmental and economic circumstances to dictate targets in the Second Stage. Bhagwati (1996) gives a cogent analysis of the arguments for and against harmonizing environmental policies. In general, the presumption is against harmonization. In our context, harmonization of targets may not be required though harmonization of regulatory modes might be important.

The layout of the Chapter is as follows. Section 1 shows firms' optimal output and abatement choices given their domestic environmental regime. I restrict analysis at this point to Design and Emission Standards. Section 2 looks at the regulators' choice of targets under the two Standards. Section 3 looks at the governments' choice between these two Standards. Section 4 has a numerical example illustrating conditions under which a race to the bottom can occur under Emission Standards and the payoffs under the different instrument choices. I show the set of Nash Equilibria that obtains. Section 5 extends the analysis by comparing Design Standards to Emission Taxes. Emission taxes are identical to Emission Standards when set non-strategically in this model. Strategic taxes tend to raise the specter of a race to the bottom. Section 6 concludes.

3.2: STAGE THREE: FIRM'S REACTION FUNCTIONS

In this section I lays out firms' costs, emission technologies, and revenue functions and derive their reaction functions under Design and Emission regulation. From this we can derive optimal outputs as a function of instrument type and stringency of targets in each country. The important result in this section is that output under Design Standards is independent of the emission target. Output falls under Emission Standards as targets become more stringent. Herein lies the difference between the instruments.

[10] This differs from many international agreements that specify national targets but do not stipulate how those targets are to be achieved. Implementation is left up to national governments. The Kyoto agreement to reduce green house gas emissions and the Montreal Protocol eliminating CFCs are of this sort. See Verdier (1992) for the strategic choice of instruments under preset targets.

There is one firm in each country, denoted by Home (H) and Foreign (F). Each firm produces two goods: an output (q) that is sold at a market price (P) and a non-marketed abatement service (a) that is un-priced. Costs are increasing at non-decreasing rates for both outputs: $C_q(q,a) > 0$, $C_a(q,a) > 0$, and $C_{qq}(q,a) \geq 0$, $C_{aa}(q,a) \geq 0$. For simplicity, I assume marginal costs of production do not change with the level of abatement: $C_{qa}(q,a) = 0$. This allows us to write costs as additively separable[11]. I also assume that firms do not value abatement except in so far as it permits additional output. This means that firms will minimize abatement as much as possible. This is the same as Barrett's analysis.

Emissions are increasing in output at non-decreasing rates and decreasing in abatement at non-increasing rates: $e_q(q,a) > 0$, $e_a(q,a) < 0$, and $e_{qq}(q,a) \geq 0$, $e_{aa}(q,a) \geq 0$. Emissions are bounded above so that, for sufficiently lax regulations, a firm will not have to abate at all.[12] There are two regimes: Design Standards and Emission Standards. Under Emission Standards, a regulated firm is unrestricted in its input and output choices but cannot emit more than a pre-specified quantity of pollution, denoted E. This emission target is determined in Stage Two by the regulator. As long as E is not too high (lax), then the firm will find this a binding constraint and must abate some of its pollution. Design Standards differ in that the firm's output is unrestricted but it must install a minimum amount of abatement capital, denoted as A. The regulator has perfect knowledge so can choose A such that, in equilibrium, the firm achieves any particular emission target desired.

Each firm chooses outputs and abatement simultaneously taking rival output, emission targets, and regulatory regimes as given. Marginal revenues are positive but decreasing in rival output: $R_i(q_i,q_{-i}) > 0$ and $R_{ij}(q_i,q_{-i}) < 0$ for $i,j = H, F$. This ensures unregulated firms have downward sloping reaction functions. I assume a unique stable equilibrium exists.

Consider the home firm's problem given its emission target and regulatory regime:

$$\mathbf{Max}_{qa}\ \pi^h(q^h,a^h,q^f) = R^h(q^h,q^f) - C(q^h,a^h) = R^h(q^h,q^f) - C(q^h) - D(a^h)$$

Subject to one of the following constraints: **(E)** $\quad e(q^h,a^h) \leq E^h \quad$ **or**

(D) $\quad a^h \geq A^h$.

[11] Non-separability implies the presence of cost complementarities where abatement expenditures can lower, or raise, marginal production costs. Barbera and McConnell (1990) show that either can occur. This means regulations can raise output even as it raises average costs. However, as long as cost complementarities are small, output effects will tend to be small and so safely ignored.

[12] This avoids the awkward position of having infinite emissions from a finite output.

The firm's first order necessary condition for an (interior) optimum with a binding Emission Standard is: $R^h_1 = C^h_q(q^h,a^h) - D^h_a(q^h,a^h)\ [e^h_q(q^h,a^h) / e^h_a(q^h,a^h)]$. The firm chooses its output so that the marginal revenue of additional output equals additional costs where these costs include the abatement required to comply with the regulation. This additional cost is positive since $D^h_a(q^h,a^h)$ and $e^h_q(q^h,a^h)$ are positive but $e^h_a(q^h,a^h)]$ is negative. Note that, as rival output grows, own output falls: $\partial q^h/\partial q^f < 0$ and so Emission Standards maintain the downward sloping reaction functions of unregulated firms. Notice also that if the quota were not binding, then the firm would set $R^h_1 = C^h_q(q^h,0)$. The binding emission constraint therefore raises the firm's marginal costs above those of an unregulated firm. This shifts the firm's reaction function inwards *vis-à-vis* an unregulated firm. This gives us the standard result that regulations reduce a firm's competitiveness. Graphically, the firm's reaction function is the same as an unregulated firm's at low output levels but falls below at higher output levels since it has additional marginal costs due to the binding constraint.

Under a binding Design Standard, the firm's first order necessary condition for an (interior) optimum is: $R^h_1 = C^h_q(q^h, A^h) = C_q(q^h, 0)$ since the firm minimizes abatement but has no output constraint. The firm chooses its output so that the marginal revenue of additional output equals additional costs. These additional costs are the same as for an unregulated firm since marginal costs do not vary with abatement. In effect, the regulation forces the firm to undertake a fixed level of abatement thereby turning what is a variable cost under Emission Standards into a fixed cost. This means that the firm's reaction function is largely, though not identically, the same as an unregulated firm[13].

It is straightforward to show that stricter emission targets (a fall in E) will have no effect on output under Design Standards.[14] This is not true under Emission Standards since

[13] The difference is that the fixed cost truncates the firm's reaction function at a low output level. That is, if the firm receives too little rent from the foreign market, it cannot cover its abatement costs, and will choose not to produce. This truncation implies the possible existence of multiple equilibria (see Chapter 2 for further analysis). In one case we have the foreign firm producing its monopoly output and the home firm optimally choosing output equal to zero. These are both optimal responses so constitute a Nash Equilibrium. By symmetry, foreign may produce nothing. (This is similar to Tirole's (1990) discussion of blockaded entry in the context of Stackleberg Competition.) We can also have the symmetric Nash Equilibrium in which both produce a positive amount and earn positive rents. It is possible for all three equilibria to exist simultaneously. For simplicity, I will assume that only the symmetric equilibrium is possible and so avoid the complication of multiplicity. This amounts to saying that, if the foreign firm chooses its monopoly output, then the home firm remains in the market for any home emission target. Under this assumption, Design Standards, unlike Emission Standards, do not reduce domestic competitiveness. It does, of course, reduce net rents.

[14] Except to shift the truncation point along the firm's reaction function. As long as both firms can obtain positive profits in equilibrium, however, their optimal outputs will be invariant to marginal changes in emission targets.

the rise in stringency means the firm needs to abate more for any given output. It is sufficient to show that if marginal compliance costs rise with abatement, given fixed output, then stricter targets raise marginal costs. This in turn reduces optimal output. Lemma 1 establishes the conditions for which rising abatement raises marginal costs. The idea is that tighter targets will force the firm to undertake some abatement at ever-lower output levels. As long as the efficiency of abatement does not rise too much at these lower output levels, the induced abatement costs will raise the firm's marginal costs. I will assume this holds from here onwards.

Lemma 3.1: *For a given output, marginal compliance costs rise as the emission target becomes more stringent (falls) as long as the efficiency of abatement does not increase strongly with decreases in output.*

Equilibrium output is characterized by the best response pair $\{q^h, q^f\}$ where each q^i is a function of the emission targets chosen in each country as well as the regulatory regimes chosen. We now move to the optimal choice of targets under the alternative regimes.

3.3: STAGE TWO: REGULATOR'S REACTION FUNCTIONS

In this section I derive the Nash Equilibrium in emissions. One question that arises is whether the optimal emission, denoted by Barrett as the strategically optimal standard (SOS), deviates from the environmentally optimal standard (EOS). This later target sets marginal abatement costs equal to marginal damages and corresponds to a Pigouvian tax. The important result from this section is that regulators under Design Standards will always set their targets equal to an EOS. This does not mean that the EOS is always independent of the environmental target chosen by the other country. The EOS is a *function* of the domestic firm's output and, by extension, a function of foreign output. More domestic output raises the marginal compliance costs of achieving a given target and so forces the regulator to weaken targets. Any policy that reduces foreign output will tend to raise domestic output, and so raise the domestic EOS. Regulators under Emission Standards, as Barrett shows, set the SOS above an EOS.

Each regulator, given the regulatory regime, chooses an emission target that maximizes the sum of rents less pollution damage. Damages are positive and non-decreasing in own pollution: $G^h_e(e^h) > 0$ with $G^h_{ee}(e^h) \geq 0$. Pollution is entirely local and has no affect on productivity in either country. The only interdependence between countries is through competition in world markets.

The home regulator's problem can be written as: $\mathbf{Max_E\ \{\pi^h(q^h,a^h,q^f) - G^h(E^h)\}}$ Where output and abatement at Home can vary with targets. The first order necessary condition for an optimum can be written as:

$$\pi^h_1(*)\, dq^h/dE^h + \pi^h_2(*) da^h/dE^h + \pi^h_3(*)(dq^f/dq^h) dq^h/dE^h - G^h_E(E^h) = 0$$

Rearranging this gives us three terms:

$$[\pi^h_1(*)]\, dq^h/dE^h \quad + \quad [\pi^h_3(*)\, dq^f/dq^h]\, dq^h/dE^h \quad + \quad [\pi^h_2(*)\, da^h/dE^h - G^h_E(E^h)] \quad = 0$$

Consider a rise in emissions. The first term is the direct effect on profits of easing emissions which, by the envelope theorem, is zero; the firm adjusts output so that marginal compliance costs equal marginal revenues. The second term is the strategic effect. Since firms compete for market share, home profits fall as foreign output rises. Also, a rise in home output reduces foreign output.[15] Hence, the sign of the strategic effect is determined solely by the effect on home output of a rise in Home's allowable emissions. This is positive under Emission Standards (Ulph (1992)). The magnitude of the strategic effect is determined by both the change in Home output and the induced change in foreign output. The interaction of these two effects determines whether a race to the bottom can occur. The third term is the change in abatement costs less marginal pollution damages. As Barrett points out (pp. 331, 333), if the strategic effect is absent, then the regulator chooses emissions such that marginal abatement costs equal marginal damages. This defines the EOS. A positive strategic effect will imply marginal abatement less than marginal damages and the SOS will rise above the EOS. Much of the remainder of this Chapter relates to the strength of this strategic effect.

From the previous section we know that, under Design Standards, the firm's optimal output is independent of the domestic emission target since marginal compliance costs are independent of targets. Hence $dq^h/dE^h = 0$ and there is no strategic effect.[16] That is, the

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[15] See Barrett for the proof (p. 330).

[16] This is, of course, a direct consequence of the fixed cost nature of imposing the Design Standard. Ulph (1992) gets similar results using Emission Standards in a slightly different model. There, firms lack abatement opportunities. Hence the Emission constraint in his model corresponds to an output constraint in my model: once the constraint is imposed, changes in foreign output can have no affect on domestic output since output is fixed. Hence the strategic effect disappears. Copeland (1992) also gets this result in a model where firms invest in abatement equipment prior to competing for market share. Once abatement capital is installed, there is a one-to-one relationship between output and emissions. Consequently output cannot vary with changes in foreign output/emissions targets.

regulator cannot affect the home firm's output by manipulating its target and so it cannot affect foreign output. Since there is no strategic effect, the regulator does best by choosing the emission target that sets marginal damages equal to marginal abatement costs. The optimal emission target, under Design Standards, is an EOS.

PROPOSITION 3.1: *Optimal targets under Design Standards set marginal compliance costs equal to marginal pollution damages and so are an Environmentally Optimal Standard (EOS).*

Six comments are in order.

1. Proposition 3.1 depends on the fixed cost nature of the Design Standard. If the Design Standard imposed higher variable costs on the firm, then the regulator will have an incentive to manipulate targets and we get similar results to the Emission Standard. The strategic incentive to manipulate targets, however, will be weaker under Design Standards since marginal costs rise only a little given the firm has no explicit emission target it must meet.. See the discussion under section 3.5.2.
2. Proposition 3.1 holds regardless of the stringency of Foreign's environmental target or how it is implemented. Even if Foreign lacked any regulation whatsoever, Home would still achieve an EOS.
3. Although the **rule** for achieving an optimal target is unaffected by Foreign's regulatory environment, the **level** of the EOS is not, since the EOS is a function of domestic output. Any rise in foreign output, due to any number of things, will reduce Home output in equilibrium. It then allows the Home regulator to make the domestic emission target more stringent. In this regard, however, weak foreign regulations will tend to raise Home's stringency rather than weaken it. This is exactly opposite of the race to the bottom feared by environmentalists. Greater Foreign output, however, lowers Home profits and Welfare (see the proof for Proposition 3.6 below). This confirms industrialists' claim that weak foreign standards can hurt domestic industries.
4. Proposition 3.1 is independent of the number of firms in the Home industry since industry output is unaffected by Design Standards (as long as all firms earn positive profits). Barrett's observation that the presence of many domestic firms can force the regulator to strengthen regulations does not apply here.

5. An EOS under Design Standards will typically differ from an EOS under Emission Standards since outputs will also differ. Hence, it does not make sense to talk about the EOS for a country without also identifying the mode in which such a target is achieved.
6. Proposition 3.1 also tells us that a country's use of Design Standards partially decouple its environmental policy from its industrial policies. Environmental policies do not affect the efficacy of competitiveness policies. This means that, whatever a country's tariff policy, its environmental policy has no direct impact on competition and so can be chosen without regard to further impact on firms' competitiveness. The decoupling goes only one way since policies that affect domestic production will, in turn, alter the optimal pollution level as well. Only if Foreign uses Design Standards will Home's targets be independent of Foreign's. This is laid out in Proposition 3.2.

PROPOSITION *3.2: If Foreign uses Design Standards, then Home's optimal emission target is independent of foreign emission targets. This holds regardless of Home's choice of instrument.*

Proposition 3.2 tells us that Foreign's use of Design Standards removes one area of conflict between the nations. Foreign's target, whether optimally set or not, has no affect on Foreign production and, hence, has no bearing on Home's choice of targets. Even if Foreign were to set very lax regulations (say A = 0), a claim that Foreign is contriving to subsidize its own firm is unwarranted: the competitiveness of Foreign's industry is independent of its environmental stringency. As with Proposition 1, weak foreign emission targets DO NOT lead to a race to the bottom.[17]

If Home uses Emission Standards, then it will manipulate its targets to enhance it's firm's competitiveness in world markets. Proposition 3.3 replicates Barrett's results.

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[17] This result depends on the firm being unable to move its plant. Design Standards do not raise marginal costs but do raise average costs. This lowers profits. If the firm could move to the other jurisdiction it might depending on the existence, and size, of any sunk/fixed costs. I leave the plant location problem under different regulatory instruments to future research.

PROPOSITION 3.3: *Strategic Optimal Standards under Emission Standards set marginal compliance costs less than marginal pollution damages and so rise above the Environmentally Optimal Standard.*

Proposition 3.3 holds regardless of Foreign's regulatory regime or targets. Note, however, that the level chosen for the SOS is a function of Foreign's regime and targets. Home's SOS is generally lower, and never higher, in equilibrium when Foreign uses Design Standards than when it uses Emission Standards. This is established in the following Lemma.

LEMMA 3.2: *Home's Strategic Optimal Target under Emission Standards is higher when Foreign uses Design Standards than when it uses Emission Standards.*

The intuition is straightforward. When Foreign uses Design Standards rather than Emission Standards, the strategic effect facing Home's regulator is stronger. The issue is the degree to which the foreign firm can adjust its output to changes in Home's output, given Foreign's regulatory constraints. Under Design Standards, the foreign firm has no effective constraint so can alter its output easily. Under Emission Standards, its marginal compliance costs are higher and so its ability to alter output is somewhat restricted. To see this consider the case where marginal abatement costs are extremely high and home tightens its target. This reduces Home output. Foreign output barely rises since the high abatement costs mean that Emission Standards are almost equivalent to output restrictions. The foreign firm would like to take advantage by expanding trade but cannot due to their constraint. This is not the case when Foreign uses Design Standards. In that case, Foreign's marginal costs are unaltered by the high marginal abatement costs and so can easily fill the void left by Home. Foreign's use of Design Standards effectively forces the Home regulator to choose slacker targets so as to maintain market share. Note that Design Standards are equivalent, from Home's perspective, to Foreign using Emission Standards but choosing to leave its firm unregulated.

Lemma 3.2 implies that countries that chose to unilaterally adopt Emission Standards in a world where its competitors use Design Standards may find that it triggers a domestic race to the bottom. Foreign countries remain regulated but its firms act in product markets as if unregulated. This suggests that coordination of regulatory modes may be required to avoid a race to the bottom.

3.4: STAGE ONE: GOVERNMENT'S REACTION FUNCTIONS

In this section I look at each Government's choice of regulatory regime. Like Regulators, each wishes to maximize producer surplus less environmental damage. To do so the governments must anticipate the actions of both Regulators and firms at home and abroad. The choice is complex since there are a number of forces at work. If the government chooses the Emission Standard, it is inviting its regulator to manipulate domestic targets. In an optimal delegation framework this may be advantageous. On the other hand, Emission Standards raise firms' marginal costs and so reduces the Home firm's competitiveness in world markets. If both choose Emission Standards, then this rise in marginal costs can be mutually advantageous since it will raise rent extraction. Design Standards, on the other hand, remove the delegation advantage since the regulator cannot affect marginal costs. However, the fixed cost nature of Design Standards endows the domestic firm with low marginal costs so is a credible commitment to higher output. This is valuable asset in Cournot Competition though it can lead to rent dissipation if both choose Design Standards. The possible combinations are complex so no attempt is made to enumerate all possible outcomes. Instead, a numerical example is offered in the next section showing conditions under which a complete race to the bottom can exist. I also show the set of Nash Equilibria in instruments.

The model is strongly biased against Design Standards since they promote maximal rent dissipation whereas Emission Standards enhance rent extraction. If targets are chosen cooperatively, Emission Standards always offer higher welfare than Design Standards. This can occur <u>even if</u> there are no pollution damages. The idea is that binding Emission targets force firms to reduce output thus raising rent extraction.[18] This can be beneficial as long as the induced abatement costs are not too high. This is the case in the simulations that follow. Design Standards cannot be manipulated to extract rents so do not offer this advantage. The following two Propositions describe these superior outcomes under cooperative Emission Standards.

[18] This is similar to Barrett's point that with many domestic firms, the Home regulator may wish to set tighter targets than the EOS (p 335).

PROPOSITION 3.4: *Cooperatively set emission targets yield higher welfare under Emission Standards than under Design Standards.*

PROPOSITION 3.5: *Cooperatively set Emission Standards can raise Welfare even if pollution damages are zero.*

Note that the absence of a strategic effect under Design Standards means that the Nash Equilibrium targets are the same as the Cooperative outcome. That is, each country gets to choose its own targets that equalize marginal abatement costs with marginal pollution damages. No explicit or implicit coordination can improve upon these unilateral policies.

Most importantly, if regulators behave non-cooperatively, but non-strategically, then they also do better under Emission Standards. That is, suppose regulators do not account for the effect their targets have on foreign firms and so ignore the rent-shifting payoff. The strategic element in the regulator's first order condition $[dq^f/dq^h]dq^h/dE^h$ becomes zero. Their target choice will become an EOS. Note that this differs from an EOS under Design Standards since outputs will also differ. This gives the following proposition:

PROPOSITION 3.6: *The Nash Equilibrium in non-strategic Emission targets yields higher welfare than the Nash Equilibrium in Design targets. Targets are also lower under non-strategic Emission Standards.*

Proposition 3.6 derives from two factors. First, for a given Foreign output and a given Home target, Home always has higher welfare under Emission Standards than under Design Standards. This follows since the Home monopolist is able to adjust BOTH output and abatement to maximize profits under Emission Standards and so attain the target more efficiently.[19] Since it cannot adjust abatement under Design Standards, the monopolist produces more and spends more on abatement. It is this increase in efficiency that seems to be driving much of the push for incentive based regulation. Second, Home's welfare, under either standard, is declining in foreign output. This occurs since Home's residual demand,

[19] This holds when home has more than one firm as well. It need not hold if output is domestically consumed since consumers' surplus rises with output.

and profits, fall as foreign output rises. When regulators choose targets non-strategically, equilibrium output is lower under Emission Standards due to the rise in marginal costs. It is this combination of increased efficiency and reduced output that generates the superior outcome under Emission Standards. Proposition 3.6 establishes clearly, then, that it is only the strategic manipulation of targets under Emission Standards that can make them worse than Design Standards.

When the strategic incentive to manipulate targets under Emission Standards is strong, the countries can end up with a race to the bottom. The next section shows conditions under which this occurs. When this occurs, the choice of Design Standards becomes a (weakly) dominant strategy. That is, if the Foreign Regulator imposes slack Emission Standards, or if they use Design Standards, then outcomes for Home are never worse when they use Design Standards. This implies that, whenever a race to the bottom might occur, governments would never choose Emission Standards over Design Standards. Therefore, as long as Design Standards are a part of the regulatory arsenal, a race to the bottom can always be avoided.

PROPOSITION 3.7: *If the Subgame-Nash Equilibrium in Strategic Emission targets yields a race to the bottom, then Design Standards yield higher welfare. Furthermore, Design Standards become a (weakly) dominant strategy.*

Proposition 3.7 also tells us that, as long as a country has access to Design Standards, it can, and will, impose some form of binding regulations regardless of the regulatory stance taken by foreign countries. It may prefer to see binding regulations abroad, but it is never forced into deregulating a domestic industry because of international competitive pressures. Design Standards, in this regard, offer a fall back position that affords some environmental protection.

3.5: A NUMERICAL EXAMPLE:

The following section offers a parameterization demonstrating some of the points made above. One focus is the conditions under which a race to the bottom exists under Emission Standards. I also show the set of Nash Equilibria in instrument choice.

3.5.1 Functional Forms

Emissions are strictly linear in output less abatement (by choice of units): $\mathbf{e(q,a) = q - a}$. Firms' costs are $\mathbf{C(q,a) = c\ q + d\ (a^2)/2}$. The increasing marginal abatement costs ensure that stricter Emission Standards raise marginal costs at increasing rates once they become binding. A rise in *d* raises marginal abatement costs. Pollution damages are increasing in emissions at increasing rates: $\mathbf{D(e) = b\ e^2}$. A rise in *b* raises marginal damages for any emission level. Demand in world markets is linear in total sales: $\mathbf{P(Q) = K - s\ (Q)}$ where Q is output from both Home and Foreign and $K > c$. An important part of the simulation is to vary the parameters *d* and *b* to see how the choice of targets and regimes change.

3.5.2 Cases:

There are four possible cases under Design and Emission Standards. Let the ordered pairs (DD, DE, ED, and EE) denote the instruments chosen by Home and Foreign.

I broke the analysis into two parts. First, I solved the model analytically to identify the symmetric Nash equilibrium values for targets for the given set of regimes. This corresponds to Stage Two in the model. These results are general to the linear demand and cost functions chosen. I identify how equilibria change as model parameters change. In particular, I identify necessary conditions for a race to occur. I have appended these calculations to Appendix One. A summary of those results is:

- For (DD), emission targets are independent. They rise in marginal abatement costs or damages.
- A race to the bottom in (EE) occurs only at combinations of low marginal damages and intermediate marginal abatement costs. Any combination of high marginal damages and either low or high abatement costs preclude the race. We would never see a race when emissions are very toxic. Nor if abatement is very easy or extremely difficult.
- Design Standards that affect variable costs rather than fixed costs may increase or decrease the likelihood of a race to the bottom. The issue is how much Design Standards raise marginal compliance costs. It is possible that, under Emission targets, marginal compliance costs are extremely high while under Design Standards they are in the middle range. This would eliminate the race under Emission Targets and produce it under Design Standards. Note that both Kalt's and Esty's claim would be fully

consistent with this scenario. However, if the impact on marginal costs were small then no race occurs under Design Standards.

- The (DD) equilibrium yield higher pollution levels than (EE) when abatement costs are high or marginal damages are high.
- For (ED), the likelihood that the Home is unregulated rises.

In the second part of the analysis, I pick particular demand and marginal cost parameters and identify the Nash equilibrium choice of Design or Emission Standards. This is Stage One in the model. I have to pick particular parameter values since direct comparisons of equilibrium welfare payoffs across regimes are difficult to make. The choice of parameters illustrates the results above. In addition to the above I found that:

- There are no asymmetric equilibria. Both countries choose Design Standards (DD) or both choose Emission Standards (EE). (DE) and (ED) never form a Nash-Equilibrium.
- (DD) forms the unique Nash Equilibrium whenever a race to the bottom occurs with (EE). It is Pareto Efficient.
- (EE) forms the unique Nash Equilibrium at high marginal damages and abatement costs. It is Pareto Efficient.
- There exist multiple equilibria in which (DD) and (EE) both form best-response pairs. Whenever this occurs, (EE) Pareto Dominates (DD) but could not be achieved unilaterally.
- There exists the possibility of a Prisoner's Dilemma in (DD). This only occurs when abatement costs are small and marginal damages high.
- An ability to commit to (EE) can raise joint welfare when marginal damages are high and marginal compliance costs low.

3.5.3 Simulation Results

Here I focus on the Nash equilibria in Stage One where governments pick their regimes. Equilibria are calculated for specific values of b and d. These are depicted in **FIGURES 3.1** and **3.2**. Some sample calculations are in **TABLES 3.1** and **3.2**. I show results using two different demand functions.

3.5.3.1 Example 1:

K = 400, s = 2, and **c = 10**. This yields the unregulated output of 65 units in Home and Foreign with unregulated emissions also at 65 units.

FIGURE 3.1a shows the ranges of *b* and *d* under which mutual use of Emission Standards yields a race to the bottom. This occurs within the shaded area on the left.[20] This is consistent with the analytical results found in the appendix (CASE EE). There I show that the race to bottom occurs only if marginal damages are not too large and when marginal abatement costs are neither high nor low. The intuition is straightforward. Consider marginal abatement costs. When marginal abatement costs rise slowly with output (corresponding to a small *d*), the restrictive effect on <u>own output</u> of a fall in targets (*dq/dE*) is small. Hence, the strategic effect is also small and the targets are binding since the SOS approaches the (binding) EOS. On the other hand, high values of *d* lead to binding emissions as well. The intuition is that when marginal abatement costs rise very quickly with output (a large *d*), the effect of own output on <u>rival output</u> (dq^F/dq^H) is also small. For instance, imagine if marginal compliance costs were infinite. A binding Emission target then becomes equivalent to an output constraint and so q = E with a = 0. Changes in own output will have zero impact on foreign output since the foreign firm will not, and cannot, alter its own output given its target. Hence, as *d* approaches infinity, the strategic effect also disappears. The SOS again approaches an EOS and is binding. Consequently, as long as marginal abatement costs rise quickly, we would not expect to see unregulated markets. Nor do we expect to see unregulated firms if abatement costs are low. Only at intermediate values of *d* does the restrictive effect on own output, and the induced effect on foreign output, be strong enough to create a sufficiently large incentive for regulators to end up deregulating their domestic firm.

Now consider marginal damages. As ***b*** goes to infinity, the high marginal damages give each country a unilateral incentive to reduce emissions. Optimal targets under (EE) go to zero. Each willingly cuts own output to reduce damages. On the other hand, as ***b*** goes to zero, countries have no incentive to reduce emissions unilaterally. They may if they cooperate.

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[20] This range was found by assuming the emission target was set so that it was just non-binding at 65 units. Note that this is not the same as being fully unregulated. By setting the target at 65, the regulator is implementing the emissions that would obtain if both firms were unregulated but it does not force the firm to abate. Allowing the target to rise above 65 increases the range over which the race occurs since it increases the strategic effect. See Lemma 2 for a discussion. Ensuring that emissions do not rise above the unregulated equilibrium further biases the results against Design Standards.

As shown in Appendix One, the maximum value for b for which a race to the bottom occurs is at $\boldsymbol{d} = (s\sqrt{3})$. Therefore, if s = 2 and b ≥ 0.1340, then the Nash equilibrium (EE) always generates binding targets. This is confirmed in **FIGURE 3.1a**.

The shaded area on the bottom right of **FIGURE 3.1a** shows the combinations of parameters for which equilibrium emissions under (EE) are more stringent than under (DD). This confirms that emissions need not be lower under (DD) despite the absence of a strategic effect.

FIGURE 3.1a: RACE to the BOTTOM under EMISSION STANDARDS: example 1
K=400, s=2, c=10

UNREGULATED MARKETS UNDER (EE)

(DD) WITH HIGHER WELFARE THAN (EE)

(DD) WITH HIGHER TARGETS THAN (EE)

MARGINAL DAMAGES (b)

MARGINAL COSTS (D)

	0.05	0.06	0.07	0.08	0.09	0.10	0.11	0.12	0.13	0.14	0.15	0.16	0.17	0.18	0.19	0.20	0.30	0.40	0.50
0.7			49.3	52.4	27.1	3.1	-20	-42	-63	-83	-102	-120	-138	-155	-171	-187	-315	-408	-479
0.8			44.0	56.3	46.0	20.8	-3.4	-27	-49	-70	-91	-110	-129	-148	-165	-182	-324	-429	-510
0.9			39.8	51.0	63.2	37.0	11.8	-12	-36	-58	-80	-101	-121	-140	-159	-178	-331	-447	-538
1			36.3	46.6	58.0	51.6	25.6	0.5	-24	-47	-70	-92	-113	-133	-153	-173	-337	-463	-562
2			19.3	25.0	31.4	38.4	46.1	54.3	44.4	16.3	-11	-38	-65	-91	-116	-141	-367	-558	-721
3			13.2	17.1	21.5	26.4	31.8	37.6	43.8	26.4	-2.7	-31	-60	-88	-115	-142	-394	-616	-814
4			10.0	13.0	16.4	20.1	24.2	28.7	33.5	15.2	-14	-44	-73	-102	-130	-158	-423	-663	-881
5			8.1	10.5	13.2	16.3	19.6	23.2	26.7	-3.5	-33	-63	-92	-122	-150	-179	-451	-702	-934
6			6.7	8.8	11.1	13.6	16.4	19.5	5.9	-24.3	-54	-84	-114	-143	-172	-201	-478	-736	-978
7			5.8	7.6	9.5	11.7	14.2	15.7	-15	-45	-75	-105	-134	-164	-193	-222	-502	-765	-1014
8			5.1	6.6	8.4	10.3	12.4	-4.0	-34	-65	-94	-124	-154	-183	-213	-242	-523	-790	-1044
9			4.5	5.9	7.5	9.2	8.1	-22	-53	-83	-113	-142	-172	-201	-231	-260	-543	-813	-1071
10			4.1	5.3	6.7	8.3	-8.8	-39	-69	-99	-129	-159	-188	-218	-247	-276	-560	-832	-1094
11			3.7	4.8	6.1	6.1	-24	-54	-85	-114	-144	-174	-203	-233	-262	-291	-576	-850	-1114
12			3.4	4.4	5.6	-8.2	-38	-69	-99	-128	-158	-188	-217	-247	-276	-305	-590	-866	-1132
13			3.2	4.1	5.2	-21.2	-51	-81	-111	-141	-171	-200	-230	-259	-288	-317	-603	-880	-1148
14			2.9	3.8	-3.0	-33.2	-63	-93	-123	-153	-182	-212	-241	-271	-300	-329	-615	-892	-1162
15			2.7	3.6	-14.1	-44.1	-74	-104	-134	-163	-193	-222	-252	-281	-310	-339	-626	-904	-1175

(number is difference between welfare under (DD) and (EE))

There are three kinds of equilibria for this example: (DD) only, (EE) only, and both (DD) and (EE). (DE) and (ED) are never equilibria. **FIGURE 3.1b** shows the set of Nash Equilibria in pure strategies obtained in Stage One of the game. **TABLE 3.1** shows some of the payoffs for different parameter values.

For the entire range of parameters *b* and *d* chosen, (DD) is a Nash-equilibrium. The unilateral deviation to Emission Standards either forces a country to choose slack targets or, if binding, lose too much market share. This is sufficient to ensure that no country chooses Emission Standards when the other chooses Design. Verdier noted this strategic commitment to high output levels.

For some of the parameter values (EE) is also an equilibrium choice. Binding Emission Standards generate higher payoffs by restricting output. Any unilateral deviation to Design Standards becomes a bad idea. It raises own and industry output too much, dissipates rents, and potentially raises emissions as well. Although the country that chooses D extracts more rents, it is not sufficient to outweigh the higher abatement costs that can result and so does not pay to deviate. This happens only when marginal damages and abatement are high.

Whenever (EE) yields unregulated markets, (DD) becomes the only Nash equilibrium. This confirms that a race to the bottom is not inevitable; it can be avoided. The uniqueness of (DD) is largely restricted to this range of parameters.

Interestingly, for some range of parameters, a Prisoner's Dilemma emerges where (DD) is the only equilibrium but offers lower Welfare than (EE). The problem here is that Design Standards offer a commitment to high output levels. This allows it to perform well against Emission Standards in some instances. However, when marginal abatement is low but marginal damages high, countries will unilaterally deviate to D if the other uses P. They do this since the rise in market share offsets the rise in emissions (see TABLE 3.1 with b=0.5 and d=0.07). Countries will also unilaterally deviate to D if the other uses D since this recaptures market share. However. When both choose D, output is too high and dissipates rents. Emissions are also high enough to be damaging. Coordination into (EE) would lower output and emissions and so raise Welfare. Neither wishes to go it alone.

FIGURE 3.1b: NASH EQUILIBRIA : example 1
K=400, s=2, c=10

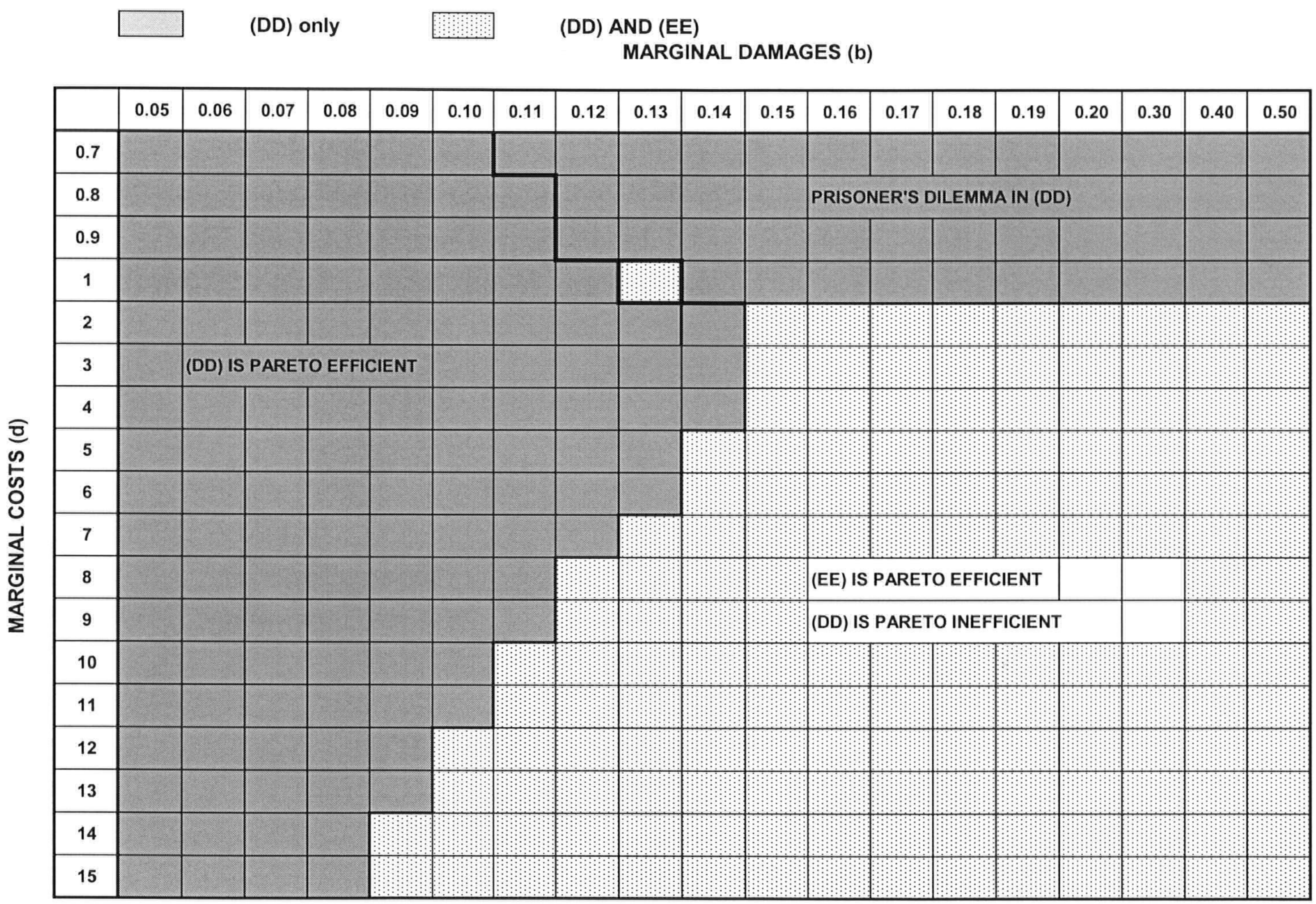


TABLE 3.1 EQUILIBRIUM VALUES: example 1
K=400, s=2, c=10

		b=0.7				b=0.10				b=0.20				b=0.50			
		(DD)	(DE)	(ED)	(EE)	(DD)	(DE)	(ED)	(EE)	(DD)	(DE)	(ED)	(EE)	(DD)	(DE)	(ED)	(EE)
d = 0.7	OUTPUT	65.00	65.00	65.00	65.00	65.00	65.09	64.82	64.62	65.00	66.39	62.22	63.35	65.00	68.25	58.49	61.44
	TARGETS	16.67	16.67	0.00	0.00	22.22	22.11	1.48	5.58	36.36	35.00	22.62	24.26	58.82	56.76	52.93	52.48
	PROFITS	8409	8409	8450	8450	8377	8400	8438	8495	8254	8612	8212	8584	7938	8753	7712	8536
	WELFARE	8204	8204	8154	8154	8121	8144	8028	8118	7912	8255	7706	8099	7580	8358	7244	8059
d = 4.0	OUTPUT	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00	63.71	65.00	68.33	58.33	59.21
	TARGETS	3.38	3.38	0.00	0.00	4.76	4.76	0.00	0.00	9.09	9.09	0.00	4.95	20.00	15.90	17.95	22.27
	PROFITS	8440	8440	8450	8450	8431	8431	8450	8450	8380	8380	8450	8603	8112	8965	7922	8918
	WELFARE	8164	8164	8154	8154	8048	8048	8028	8028	7682	7682	7605	7840	6760	7471	6500	7641
d = 10	OUTPUT	65.00	65.00	65.00	65.00	65.00	65.00	65.00	64.66	65.00	65.00	65.00	62.64	65.00	67.00	61.78	57.52
	TARGETS	1.38	1.26	0.00	0.00	1.96	1.79	0.00	0.73	3.85	3.51	0.00	5.08	9.09	5.52	5.94	16.11
	PROFITS	8446	8446	8450	8450	8442	8443	8450	8494	8419	8421	8450	8728	8275	8806	8227	9131
	WELFARE	8158	8158	8154	8154	8036	8035	8028	8077	7638	7635	7605	7966	6530	6920	6358	7644
d = 15	OUTPUT	65.00	65.00	65.00	65.00	65.00	65.00	65.00	64.66	65.00	65.00	65.00	62.64	65.00	66.61	61.78	57.52
	TARGETS	0.92	0.92	0.00	0.00	1.32	1.32	0.00	0.73	2.60	2.60	0.00	5.08	6.25	3.93	5.94	16.11
	PROFITS	8447	8447	8450	8450	8445	8445	8450	8494	8429	8429	8450	8728	8326	8743	8227	9131
	WELFARE	8157	8157	8154	8154	8033	8033	8028	8077	7627	7627	7605	7966	6470	6794	6358	7644

TABLE 3.2 EQUILIBRIUM VALUES: example 2
K=100, s=1, c=10

		b=0.02				b=0.06				b=0.20				b=0.50			
		(DD)	(DP)	(PD)	(PP)	(DD)	(DP)	(PD)	(PP)	(DD)	(DP)	(PD)	(PP)	(DD)	(DP)	(PD)	(PP)
d = 0.6	OUTPUT	30.00	30.00	30.00	30.00	30.00	30.00	30.00	29.87	30.00	31.40	27.20	28.32	30.00	32.65	24.71	26.98
	TARGETS	6.25	6.25	0.00	0.00	16.67	16.67	0.00	2.63	40.00	37.20	32.64	33.52	70.00	59.19	61.76	60.42
	PROFITS	898.9	898.9	900.0	900.0	892.5	892.5	900.0	903.8	856.8	938.6	839.4	923.6	767.7	940.9	754.0	903.9
	WELFARE	883.1	883.1	882.0	882.0	855.0	855.0	846.0	852.6	792.0	867.6	757.8	844.0	711.0	866.0	688.2	833.4
d = 4.0	OUTPUT	30.00	30.00	30.00	30.00	30.00	30.00	30.00	29.94	30.00	30.32	29.35	27.61	30.00	33.80	22.40	24.27
	TARGETS	0.99	0.99	0.00	0.00	2.91	2.91	0.00	0.32	9.09	8.11	2.96	13.94	25.93	9.86	34.84	33.44
	PROFITS	899.8	899.8	900.0	900.0	898.5	898.5	900.0	901.7	885.1	904.3	890.0	953.9	779.0	1051.1	740.8	969.3
	WELFARE	882.2	882.2	882.0	882.0	847.6	847.6	846.0	848.0	736.4	752.3	720.5	820.6	433.3	685.5	549.8	769.9
d = 10	OUTPUT	30.00	30.00	30.00	30.00	30.00	30.00	30.00	29.51	30.00	30.00	30.00	27.13	30.00	33.83	22.35	23.40
	TARGETS	0.40	0.40	0.00	0.00	1.19	1.19	0.00	2.11	3.85	3.85	0.00	12.44	12.28	-2.51	29.34	28.58
	PROFITS	899.9	899.9	900.0	900.0	899.4	899.4	900.0	914.0	893.3	893.3	900.0	965.9	832.1	1097.0	749.3	991.3
	WELFARE	882.1	882.1	882.0	882.0	846.6	846.6	846.0	862.3	726.9	726.9	720.0	827.9	347.4	624.2	524.6	761.8
d = 15	OUTPUT	30.00	30.00	30.00	30.00	30.00	30.00	30.00	29.34	30.00	30.00	30.00	26.96	30.00	33.81	22.37	23.14
	TARGETS	0.27	0.27	0.00	0.00	0.79	0.79	0.00	2.64	2.60	2.60	0.00	12.18	6.25	-5.67	27.97	27.42
	PROFITS	900.0	900.0	900.0	900.0	899.6	899.6	900.0	918.8	895.4	895.4	900.0	970.0	873.6	1109.9	752.1	997.6
	WELFARE	882.0	882.0	882.0	882.0	846.4	846.4	846.0	867.6	724.7	724.7	720.0	831.2	478.1	607.4	518.6	760.5

3.5.3.2 Example 2:

K = 100, s = 1, and **c=10**. Here I decrease market demand and the scale of unregulated firms. This yields unregulated output and emissions of 30 units in Home and Foreign. These values were chosen since the set of Nash Equilibria differ somewhat from Example 1.

The shaded are on the left of **FIGURE 3.2a** show the range of parameters that yield a race to the bottom. With the smaller scale and higher elasticity, the race becomes less likely. The range where (EE) yields stricter targets than (DD) (shaded area to the right) expands as well. As before, (DD) yields higher payoffs more or less if (EE) yields a race to the bottom. For almost all other values (EE) has a higher payoff.

The set of Nash Equilibria in pure strategies is also similar but differ in that there is now a combination of parameter values for which (EE) is a unique Nash equilibrium. It is also Pareto Efficient. It occurs when both marginal damages and abatement are high. In this range, a unilateral deviation to D, from E, worsens a country's welfare. This occurs primarily because the country that deviates to D ends up with higher emissions than the country that stays with E. In fact, for high values of *d* and *b*, emissions can rise above the unregulated level of 30 since output also rises above 30. (See **TABLE 3.2** where d = 15 and b = 0.50 yields a rise in output of 12.7% and emissions of 5.67% when Home chooses D while Foreign chooses E). The country that deviates gains profits but not enough to cover the additional pollution damages. Furthermore, each country has an incentive to choose E given the other chooses D. In effect, the country forces its own industry to severely contract thus reducing emissions significantly. For d = 15 and b = 0.50 the country that chooses E reduces output by 25.4% and emissions by 27.97%. This effect is similar to the NIMBY (Not In My Back Yard) Principle where pollution damages are so high that it is preferable to eliminate production rather than suffer the pollution. It differs in that the target is NOT lower than the respective EOS.

FIGURE 3.2a: RACE to the BOTTOM under EMISSION STANDARDS
K=100, s=1, c=10

UNREGULATED MARKETS UNDER (EE)

(DD) WITH HIGHER TARGETS THAN (EE)

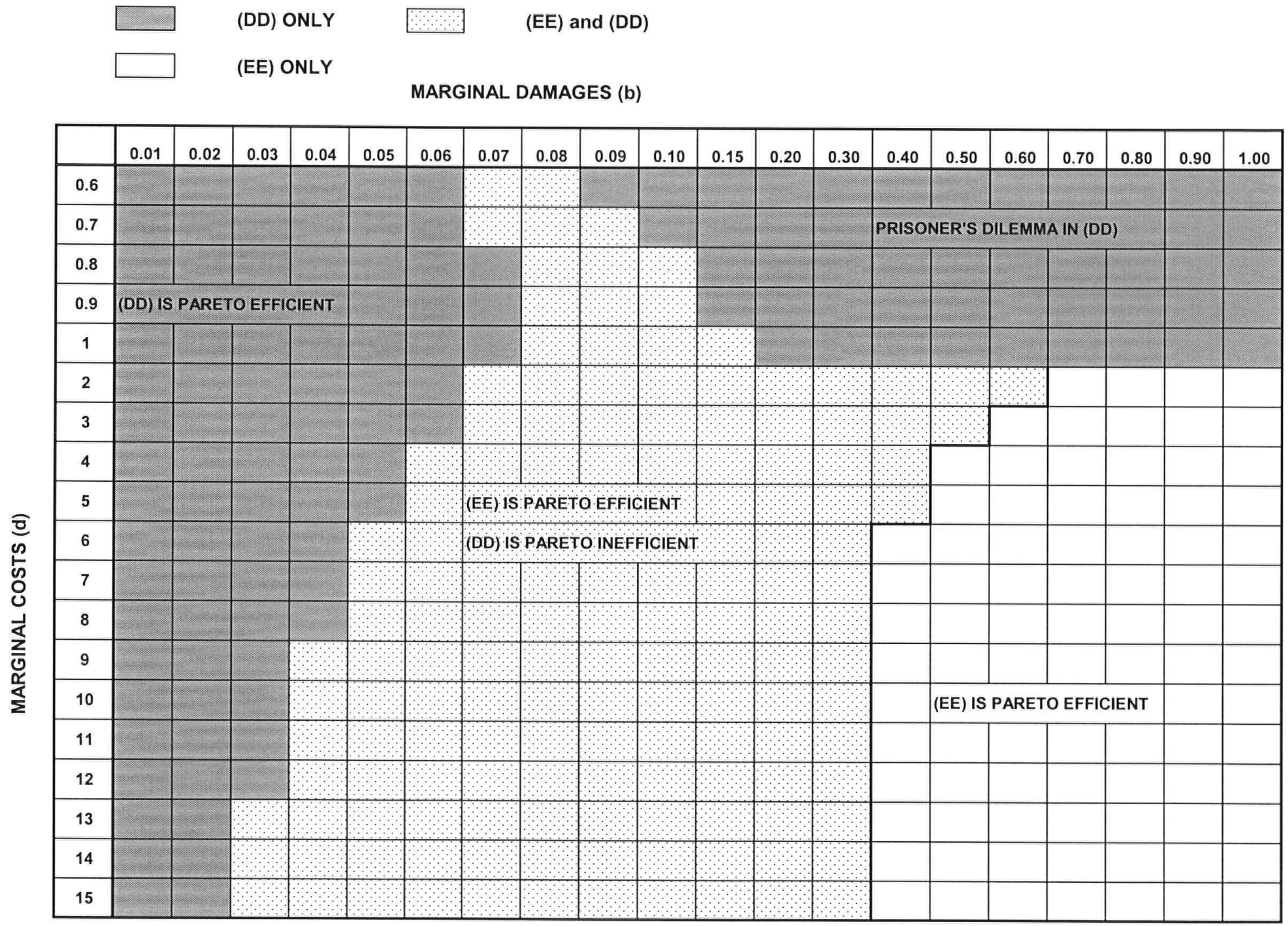
(DD) WITH HIGHER WELFARE THAN (EE)

MARGINAL DAMAGES (b)

MARGINAL COSTS (d)

	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10	0.15	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00
0.6	0.29	1.13	2.45	4.24	6.43	2.42	-2.97	-8.0	-12.8	-17.4	-37	-52	-75	-90	-102	-111	-119	-124	-129	-133
0.7	0.25	0.97	2.13	3.69	5.62	4.32	-1.31	-6.6	-11.7	-16.5	-37	-54	-229	-98	-112	-123	-132	-139	-145	-150
0.8	0.22	0.86	1.88	3.27	5.00	5.81	0.00	-5.5	-10.8	-15.8	-38	-56	-84	-105	-121	-134	-144	-153	-160	-166
0.9	0.20	0.8	1.7	2.9	4.50	6.35	1.00	-4.7	-10.1	-15.4	-39	-58	-88	-111	-129	-143	-155	-165	-173	-181
1	0.18	0.69	1.53	2.67	4.09	5.79	1.74	-4.07	-9.7	-15.0	-39	-59	-92	-117	-136	-152	-166	-177	-186	-195
2	0.09	0.35	0.79	1.38	2.14	3.06	1.62	-4.7	-10.8	-16.8	-45	-71	-115	-153	-186	-214	-239	-261	-281	-299
3	0.06	0.24	0.53	0.94	1.45	2.08	-2.6	-9.0	-15.2	-21.4	-51	-78	-128	-173	-213	-249	-282	-312	-340	-365
4	0.04	0.18	0.40	0.71	1.10	-0.43	-6.9	-13.2	-20	-26	-56	-84	-137	-185	-230	-271	-310	-345	-379	-410
5	0.04	0.14	0.32	0.57	0.88	-4.16	-10.6	-17	-23	-29	-60	-89	-143	-194	-242	-287	-329	-369	-407	-443
6	0.03	0.12	0.27	0.47	-0.9	-7.3	-13.7	-20	-26	-32	-63	-92	-148	-201	-251	-298	-344	-387	-428	-468
7	0.03	0.10	0.23	0.41	-3.5	-9.9	-16.3	-23	-29	-35	-65	-95	-152	-206	-258	-307	-355	-401	-445	-488
8	0.02	0.09	0.20	0.36	-5.8	-12	-18	-25	-31	-37	-68	-97	-155	-210	-263	-314	-364	-412	-458	-503
9	0.02	0.08	0.18	-1.32	-7.7	-14	-20	-27	-33	-39	-70	-99	-157	-213	-267	-320	-371	-421	-469	-516
10	0.02	0.07	0.16	-3.0	-9.3	-16	-22	-28	-34	-41	-71	-101	-159	-216	-271	-325	-377	-428	-478	-527
11	0.02	0.07	0.15	-4.4	-10.7	-17	-23	-30	-36	-42	-72	-102	-161	-218	-274	-329	-382	-434	-486	-536
12	0.01	0.06	0.13	-5.7	-12	-18	-25	-31	-37	-43	-74	-104	-163	-220	-276	-332	-386	-440	-492	-544
13	0.01	0.06	-0.50	-6.8	-13	-19	-26	-32	-38	-44	-75	-105	-164	-222	-279	-335	-390	-444	-498	-551
14	0.01	0.05	-1.51	-7.8	-14	-20	-27	-33	-39	-45	-76	-106	-165	-223	-281	-337	-393	-449	-503	-557
15	0.01	0.05	-2.41	-8.7	-15	-21	-27	-34	-40	-46	-76	-107	-166	-225	-282	-340	-396	-452	-507	-562

FIGURE 3.2b: NASH EQUILIBRIA: example 2
K=100, s=1, c=10



3.6: EMISSION CHARGES versus DESIGN STANDARDS:

In this section I compare Design Standards to Emission Charges. In general, Emission Charges behave very similarly to Emission Standards. Results parallel those above. The only significant difference is that the race to the bottom becomes more likely.

Emission Charges alter the ability of the Home firm to adjust to foreign output. Under binding Emission Standards, the firm is forced to restrain its emissions. It can raise output but must simultaneously raise abatement. This means that marginal compliance costs are increasing in output. With Emission Charges, the firm can raise output AND raise emissions. It will raise emissions as long as the additional charges are less than or equal to marginal abatement costs. Taxes then create an upper limit to marginal compliance costs. This in turn makes output more sensitive to Foreign Output. The consequence is to lower the slope of the Home firm's reaction function and so raise the strategic effect above that which obtains under Emission Standards.[21]

However, as long as regulators do not behave strategically Emission Charges will be equivalent to Emission Standards.[22] Equivalence follows since the regulator can always find a tax that equals $[- D^h_a(q^h,a^h)\ [e^h_q(q^h,a^h) / e^h_a(q^h,a^h)]$ from the firm's first order condition. Hence non-strategic Emission Charges will dominate Design Standards. Again, Esty's claim appears to be validated.

If a race can occur, Design Standards (weakly) dominate Emission Charges. As with Emission Standards, the availability of Design Standards allows the government to evade an effective deregulation of its industry.

The functional forms used in Section 3.5 showed a number of interesting results. Calculations are in Appendix One. There were five main results:

- Taxes can be either strategic substitutes or complements. Emission Standards, on the other hand, are always strategic substitutes.
- A race to the bottom is more likely under Emission Charges than under Emission Standards. This is due to the stronger strategic effect found under Emission Charges
- A race to the bottom is precluded as long as marginal damages are high. This also corresponds to the range of parameters where taxes are strategic substitutes. When

[21] Ulph (1992) and Copeland (1992) also show this.

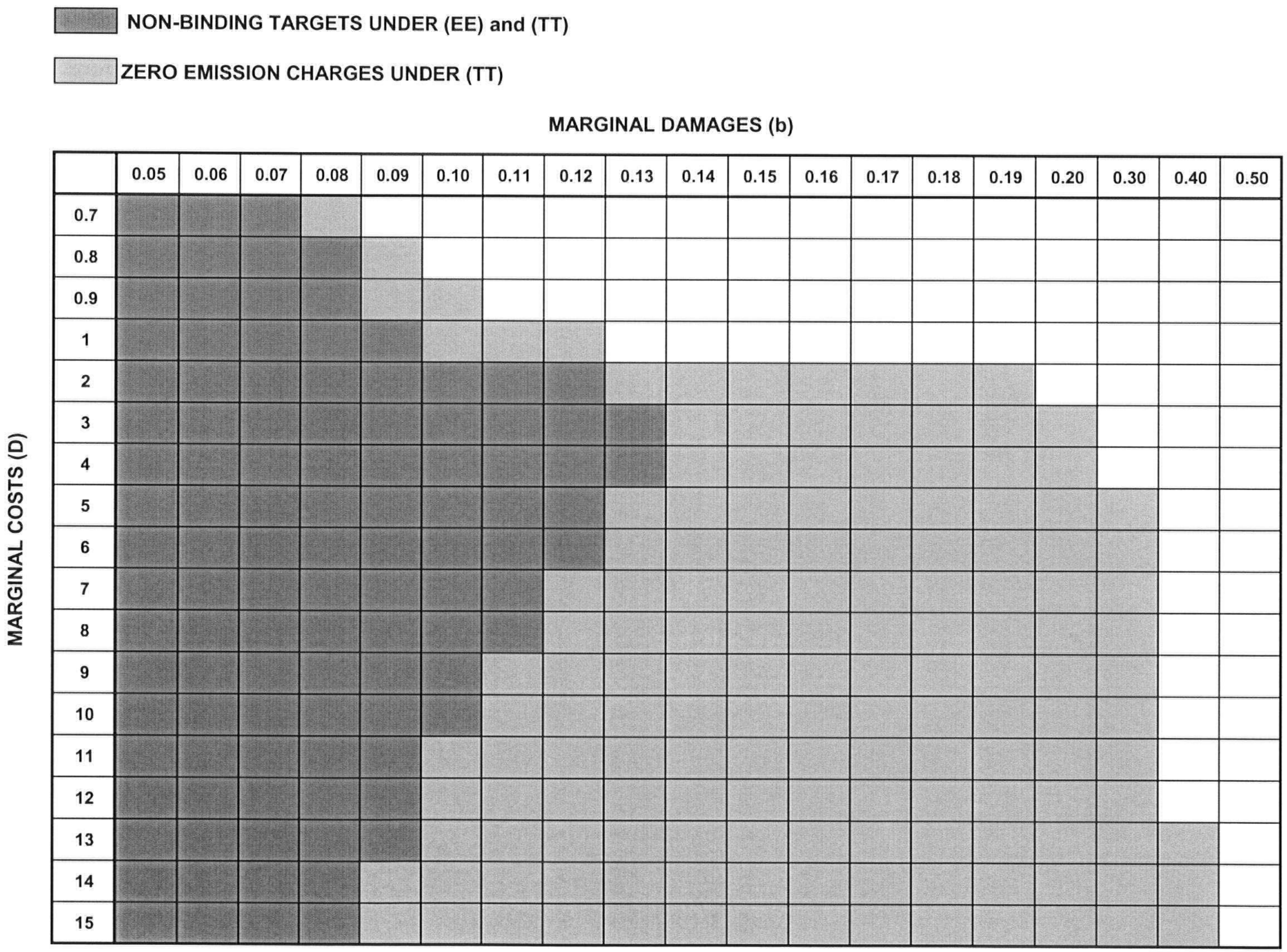
[22] See Ulph (1992) for a proof.

charges are strategic complements, the race occurs since reductions in taxes become reinforced.

- The race to the bottom is precluded as long as demand elasticity is high.
- Constraining emission charges to be non-negative turns out to be binding. Regulators, may, in fact, want negative environmental taxes. This works much like an export subsidy. Though unlikely, it does raise the concern that incentive based regulations place pressure for reduced regulations in input markets. This lowers input prices and so acts as a subsidy. This is also possible under Emission Standards. Hence, the form of regulation may trigger a general easing of targets even in non-traded markets.

FIGURE 3.3 shows the ranges of *b* and *d* under which mutual use of Emission Charges (TT) yielded taxes of zero in equilibrium. The shaded area shows where taxes are set at zero. For comparison, the more darkly shaded area shows where Emission Standards are non-binding. We see that Emission Charges, at least for these functional forms, are more conducive to a race. This is particularly true at higher marginal abatement costs.

FIGURE 3.3: RACE to the BOTTOM under EMISSION CHARGES
K=400, s=2, c=10



3.7: CONCLUDING REMARKS:

This purpose of this chapter was to analyze how a country's choice of *regulatory regime* influences their *level* of environmental protection when governments care about the international competitiveness of their industries. I compared equilibrium outcomes between technical Design Standards and Emission Standards as well as Emission Charges. I showed that Emission Standards and Emission Charges create a link between the international competitiveness of a nation's industries and the stringency of its environmental targets. This link did not exist (or is at least was weaker) under Design regulations.[23] This means, as Hansson suggests, environmental quality becomes a function of the regulatory mode chosen. That mode must be chosen carefully.

The likelihood of a race to the bottom appears strongest under Emission Charges. It is less likely under Emission Standards. It does not occur, in my framework, under Design Standards. The greater the demand elasticity, the more likely the race since regulators will have a stronger incentive to behave opportunistically. However, we would not expect a race if pollution was highly toxic. Similarly, high marginal abatement costs reduce the probability of a race under Emission Standards. This is not true with taxes. Here, once the tax goes to zero, higher marginal abatement costs become irrelevant.

Design Standards therefore offer a potential way to avoid the race to the bottom. They can isolate countries' environmental policies to some extent from those of its neighbors. They offer a fallback position for governments that allow some degree of environmental protection regardless of the regulatory position taken by foreign governments. Design Standards commit regulators to non-strategic intervention. This can be a good thing.

Consequently, a move away from our traditional Command and Control regulation, and toward more incentive based regulations, might increase the conflict between nations. Therefore Esty's claim that incentive based regulations would lower costs and so decrease tension is not fully justified. It is contingent upon whether the strategic motive to manipulate targets is weak enough to be disregarded. As long as countries do not behave strategically, both will get lower emissions and higher welfare under Emission Standards or Emission

[23] As noted, this derives from the fixed cost application of the Design Standard. However, as long as the Design Standard does not specify a particular target, the direct effect on costs is likely to engender only a small increase to marginal costs and so generate only a weak strategic incentive. The fixed costs assumption is a first approximation.

Charges. Otherwise, incentive based regulations opens a Pandora's box and permits a level of manipulation of policies that was not previously available.

I offer a caution to environmentalists. These results do not mean we should always hold to traditional Command and Control regulations. Countries that choose Design Standards may not have lower emissions than those that choose Emission Standards or emission taxes. They can suffer worse pollution. The use of Design Standards can force regulators to accept high industry pollution since its industry output may also be high. The regulator has to take into account the higher compliance costs associated with higher output and so optimally chooses high emissions. Emission Standards and taxes, on the other hand, tend to reduce industry output so allow regulators to (potentially) tighten emission targets. The point here is that it is production that imposes external costs. Emission Standards and taxes reduce domestic production so can attain stringent targets more easily. Design Standards need not reduce output and so makes targets more costly to attain.

Do unilateral instrument choice lead to sub optimal outcomes and conflict? It can. There is tension between the output promoting effects of Design Standards, which yields a strategic benefit to firms, the output constricting effect of Emission Standards and emission taxes, which raises rent extraction from world markets, and the strategic effect from manipulating targets under Emission Standards and emission taxes. The model is biased against Design Standards as an optimal instrument. In general, countries, if cooperating fully, would always choose strict Emission Standards or taxes since this constricts joint output, and so raises rents, while reducing pollution damages. Note that this could occur <u>even if</u> there were no pollution damages since unbridled competition between the nations' firms dissipate rents.[24]

The analysis suggests a possible role for harmonization of regulatory instruments without necessarily requiring countries to simultaneously harmonize emissions targets. Coordination of regulatory regimes may be important since multiple equilibria are possible and can be ranked. Countries may be reluctant to unilaterally move away from Design Standards and so get stuck in a sub-optimal equilibrium. In particular, countries that adopt Emission Standards or Emission Charges, when competitor nations continue to use Design

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[24] Profits may rise as long as abatement costs are not too heavy since the restriction in output can more than compensate for additional compliance costs. See Bruneau (2000) for a more thorough discussion of this phenomenon. See also Buchanan and Tullock (1975) for an example. Profits always fall under Design Standards. In the simulations used for the chapter, binding quotas always raised firms' profits.

Standards, may find that their regulators initiate a local race to the bottom. By coordinating a common move to more efficient regulation, we might avoid such a race.

CHAPTER 4: BORDER EFFECTS in OECD MANUFACTURING INDUSTRIES: 1970-85

4.1: INTRODUCTION

It has now become well established that trade densities tend to be much higher internally than externally. These "border effects" or "home biases" have been found in trade between Canadian provinces and American states (McCallum (1995), Helliwell (1996, 1998), and Stein and Weinhold (1997)), for intra- and inter-state trade in the US (Wolf (1996)), for intra-EU trade (Nitsch (1997)), and for intra-OECD trade (Helliwell (1998) and Wei (1996)).

Border effects are "large, pervasive, and durable" (Helliwell, 1998). For instance, Helliwell (1996, 1998) uses data from 1988 to 1996 to estimate that Canadian provinces traded around 15 to 20 times more with each other than with American states after adjusting for the economic size, distance, and relative location of the provinces and states. Wei (1996), taking a different approach and making different assumptions, estimated that in 1992 OECD countries traded, on average, 2.5 times more with itself than with an otherwise identical foreign country. Helliwell (1998) included OECD and non-OECD countries and found a border effect of around 10. Nitsch (1997) found a similar magnitude within the European Union despite a presumption of low barriers to trade. The size of these home biases is surprising large given the degree to which globalization has taken place and the systematic dismantling of trade barriers through the GATT process. The existence of large border effects suggests that either borders impose significant hidden transactions costs or that internationally traded goods are such close substitutes that even the small barriers that do exist have important effects on trade (Haveman and Hummels, 1997, p 23). The hidden transactions costs might develop from an incomplete set of international institutions that reduce the uncertainty and risk inherent in trade (Helliwell, 1998, pp 120-22).

The sources of these home biases are not yet fully identified. Wei (1996) considered exchange rate variability in different currencies as a possible source in a sample of OECD countries. The hypothesis is that, given exchange rate risks inherent to international transactions, firms will be less willing to venture abroad and so concentrate production for the home market. Wei found no evidence to support this claim. Rose (1999) gets similar results. He used a sample of 186 countries and found that exchange rate variability had only a small, though significant, negative effect on bilateral trade flows. On the other hand, Rose did find a positive and significant effect of currency unions on trade. He finds that countries that shared the same currency traded over three times as much as with countries that used their own currency (p 23). This was after accounting for exchange rate volatility. If Rose's results are accurate, then the institution of a shared currency does much to facilitate trade and would be consistent with border effects. However, the countries that shared a common currency were characterized primarily by large economies trading with very small satellites. For example, the USA and Guam, Australia and Norfolk Island, and the UK and Falkland Islands all share common currencies. Many of these satellites are likely to have shared many other common institutions as well as long administrative histories. It is uncertain to what extent these other factors account for the greater volume of trade.

Rose's approach of a common institutional factor promoting trade is analyzed in some depth by Helliwell (1998). His point was that institutions and networks that promote or facilitate trade are denser within nations than across borders. It suggests that the development of appropriate social institutions and infrastructure are important factors in promoting cross border trade. Institutional development is likely tied to the economic development of a country. There is some evidence supporting this. For instance, Helliwell showed that the lower a country's per capita income, the higher was its border effect.

Helliwell also showed that there is a great deal of variance in Canadian sectoral border effects. Some industries (food and beverages) have a very strong home bias while others low (transportation equipment between Ontario, Quebec, and Michigan). He also found that Canada's western provinces have relatively low border effects and attributed this to their reliance on commodity trade (p. 27). This raises the question whether country-specific border effects are driven primarily by differences in national production patterns. The hypothesis might be that countries with low border effects have production and trade concentrated in those industries that are highly integrated globally. Harrigan (1996) makes such a claim by arguing that "a country with a relatively large output in goods that are consumed mainly at home...will have a lower volume of exports than a country with a relatively large output of goods which are heavily traded internationally" (p29).[1]

The contribution of this paper is twofold. First, I identify border effects using a different data set spanning a different time period and different countries from the researchers noted above. The data covers bilateral manufacturing trade between 22 OECD countries from 1970 to 1985. Data comes from the Organization for Economic Cooperation (OECD) Comparable Trade and Production (COMTAP) database. The results show that border effects were high, persistent, and highly variable across countries. They were getting substantially smaller over time. The results are consistent with those previously reported. Country-specific border effects varied strongly with Belgium and the Netherlands exhibiting almost no border effects at the end of the period with Greece and Yugoslavia showing very high border effects. All the countries showed declines in their home biases over the period though these declines differed in pattern and extent. Per capita income was an important determinant of country-specific border effects.

The second contribution of the paper is an exploration of the relationship between sectoral and country-specific border effects. This aspect has not been analyzed to date. Research by Chen (2000) and Head and Mayer (2000) focus on factors that determine the pattern of border effects across sectors rather than the pattern of border effects across countries.

The data I use contains production and bilateral trade data for 30 manufacturing industries in nine sectors for the 22 countries for each year 1970 to 1985. The disaggregated data allows me to identify sector-specific border effects. Although the theoretical foundation for using disaggregated data may be weaker than that for aggregate trade (since industry specific factors that determine trade intensities become more important), it does allow me to ask some questions about possible sources of country-specific home biases. The data clearly shows that border effects vary strongly across industries. Intra-national trade in Beverage and Tobacco Manufactures is 250 times greater in 1985 than inter-national trade.

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[1] Haveman and Hummels (1997) speculate that measured border effects would disappear when consumption and production shares are controlled for (p. 23). They argue that countries that had strong consumption preferences would also have high production levels as firms satisfy that home demand. The data would exhibit border effects when, in fact, no bias had occurred. Of course this does not explain WHY countries would differ in production or consumption-shares nor why production needs to be so close to markets.

In Wearing Apparel, it is only 1.4 times greater. All industries, except Petroleum Refineries, showed declines in border effects over the period. Each declined at different rates.

I use this sectoral pattern to identify whether differences in home biases are the result of different national production patterns. I find only limited evidence. I test this in four ways. First, I construct a predicted country-specific border effect as a weighted average of sector-specific border effects using each country's production shares as weights. A psuedo-r^2 between the predicted and measured border effect yields a value of 0.12: about one-eighth of the variation in measured border effects across countries can be explained by variations in production patterns. As a comparison, I also construct a predicted country-specific border effect by accounting for each country's deviation of per capita income from the OECD mean. The psuedo-r^2 for this measure yields a value of 0.62: two–thirds of the variation in measured border effects can be explained by variations in per capita income about the OECD mean. The measured country-specific border effects are sensitive to how internal trade distances are calculated. As a robustness check, I used two different approaches and got the same result: per capita income accounts for much of the variation in country-specific border effects while production patterns did not.

Second, I look at the correlation between measured sectoral border effects for each country. The data shows that border effects were strongly correlated across sectors within a country. The overall correlation of border effects across sectors was always positive with the lowest correlation at 0.490. Rankings of border effects were more strongly correlated. The lowest (Spearman Rank) correlation was 0.532. This means that a country's relative rankings were largely maintained across its industrial sectors. For instance, Belgium, Netherlands, Germany and France have the lowest overall border effects of the 22 countries in 1985. Further, none of these countries were ranked lower than 8th in any industrial sector. Their average rankings across sectors were 2nd,1st ,3rd , and 4th respectively. The three countries with the highest overall border effects, Yugoslavia, Greece, and New Zealand, had rankings that never fell below 10th in any sector and had average rankings of 22nd, 21st, and 19th respectively. The relatively high correlation of border effects within countries is likely to hold under different measurements of internal trading distances. Countries will tend to change their relative rankings across all sectors simultaneously. This relative constancy across the sectors highlights the role pan-sectoral factors seem to matter in determining trade propensities.

Third, I use average tariff and non-tariff barriers to see whether these could explain the degree of home bias. They cannot. I use Harrigan's (1993) data on tariff levels and average coverage rates for non-tariff barriers (price, quantity and threat) in 1983 among thirteen OECD countries. Introducing formal barriers to trade had no effect on the measured border effect for that year. The reason seems to be that tariff and non-tariff barriers were positively correlated with distance: the further the trading partner, the higher the barriers to trade. This reduces the sensitivity of trade to distances. Hence trade barriers end up increasing the costs of transacting trades over large distances but cannot explain why we trade less than expected with close neighbors.

Fourth, the relationship between a country's sector specific border effect and its sectoral composition of production is counter-intuitive. Given homothetic preferences, the more a country concentrates production in a sector (say electrical equipment), the smaller will be its home bias in that sector since it will tend to use this production to finance imports in other sectors. The data shows the converse. The correlation between countries' sector-specific border effects and their production shares in those sectors was positive in six of the eight sectors. Countries that concentrated their production tended to have higher borders. Further, the greater the concentration of OECD production for a sector in a particular country, the higher was that country's home bias. Again, this is surprising since countries that produce more than their share of OECD production should trade a larger proportion of it and so rely less on home sales. This should lower their home bias, at least in that sector. It doesn't seem to be the case here.

In all, the sectoral analysis suggests that, though of some importance, the composition of a country's production is not a major factor in determining its openness to trade. Rather, the level of development, or at least GDP, is critical. The composition of production undoubtedly matters, but is dominated by pan-sectoral factors.

The layout for the paper is as follows: in section 2 I discuss methodology used in the paper and related issues particularly with respect to using the gravity model on sectoral data. In section 3 I present border effects at the aggregate level for an average OECD country and for individual countries. In section 4 I present border effects for each industry and eight industrial sectors. I also identify country-specific, sectoral border effects for the eight main sectors. In section 5 I show that the sectoral composition of national production, though important, cannot explain much of a country's aggregate home bias. I give concluding comment in section 6. Data and regression appendices follow.

4.2 METHODOLOGY:

In this section I discuss elements of the econometric model used to identify border effects and the data used.

4.2.1: Basic Gravity Equation:

The workhorse used to identify border effects is the gravity model of trade. This model posits that the volume of trade between two countries is positively related to their economic masses and negatively related to the distance between their economic centers. The gravity equation, in log form, is given as:

$$(1) \qquad \boldsymbol{ln(S_{x\,m}) = \alpha + \beta_1 ln(Y_x) + \beta_2 ln(Y_m) + \beta_3 ln(DIST_{xm}) + \varepsilon_{xm}}$$

S_{xm} is the value of exports from country x to m; Y_x and Y_m are their GDPs, adjusted for purchasing power parity (PPP); and $DIST_{xm}$ is the distance between the economic centers of the two countries. ε_{xm} is a nicely behaved error term.

A theoretical basis for the gravity model can be developed from a model of monopolistic competition under free trade (Helpman and Krugman, 1985). The premise is that goods are produced with an increasing returns to scale technology that ensures that only one firm, and hence one country, specializes in its production and export. With free trade and no transport costs, each country produces only a subset of all possible goods. Domestic consumption of good k depends on the country's share of total world income: $C_i^k = s_iY^k$ where $s_i = Y_i/Y_{world}$ and Y^k is world production of good k. Since production is fully specialized in a particular country, we have imports of country i from j as: $M^k_{ij} = s_iY^k = s_iY^k_j$ where Y^k_j is zero for some k. Summing over all industries yields $M_{ij} = S_{ji} = Y_iY_j/Y_{world}$. This gives us the simply gravity model without transport costs. The coefficients β_1 and β_2 in equation (1) are predicted to have a value of one. Introduction of transportation costs, barriers to trade, and differences in preferences is straightforward (see Harrigan 1993, 1996 or Deardorff, 1998).

To compare internal trade to external trade, one must include measures of internal shipments and internal shipping distances. For the Canada-US case, used by Anderson (1995) and Helliwell (1996,1998), internal trade data can be found directly since each Canadian province records trade with each province and US state separately. For the OECD case, internal trade is found indirectly by subtracting total exports from total gross production (as in Wei, (1996), Helliwell (1998), and Nitsch (1997)). We need to use total gross production, rather than GDP, since it includes sales of both intermediate and final goods. GDP excludes intermediate production while international trade data, of course, makes no distinction over the use of the good. Unfortunately, the need for gross production implicitly requires the existence of national input-output matrixes. This restricts analysis to mostly developed countries.

Internal distances are more difficult to impute. For the Canada-US case, internal distances are simply the distance between economic centers of each province and state. For the OECD case, we need to estimate it as some (weighted) average of internal shipping distance. I discuss this in more detail below since measured border effects are sensitive to internal distance measures.

We can add to the basic gravity equation an own-trade dummy variable that takes on a value for one if both the exporter and importer are the same country. This gives us:

$$(2) \qquad ln(S_{x\,m}) = \alpha + \beta_1 ln(Y_x) + \beta_2 ln(Y_m) + \beta_3 ln(DIST_{xm}) + \beta_4(OWN) + \varepsilon_{xm}$$

Since internal trade entails a shorter shipping distance than external trade, we expect that internal trade, all other things equal, to be higher than external trade. This distance related effect, however, is captured by the coefficient on DIST. If there is no home bias, then the parameter β_4 becomes zero: internal trade is not proportionately larger than external trade. If there is a home bias, say due to trade barriers or preference for domestic production, then internal trade in a commodity that is produced at home (M^k_{ii}) will exceed the country's share of world production in that good ($s_i Y^k_i$). Aggregate trade with other countries, on the other hand, will fall below the country's share of world income since there is a diversion of purchases from foreign to home: $M_{ij} < Y_i Y_j / Y_{world}$. Therefore, biased trade would show up as a decrease in trade flows between countries and increases internally. The coefficient β_4 would become positive. It is this coefficient that is estimated in this paper.

4.2.2: Sectoral Trade and Border Effects:

Data used in this paper is disaggregated using the International Standard Industrial Classification (ISIC), revision 2, and is restricted to manufactured goods starting with ISIC code 3. Disaggregation is at the three-digit level. **TABLE 4.1** gives the list of sectors used. Column two gives the shares of total OECD production in each three-digit category as a fraction of total ISIC3 production. Column three gives its total share of OECD exports. Notice that ISIC38 (Fabricated Metal Products, Machinery, and Equipment) is the largest sector. It also has the highest share in trade. The ratio of export share to production share indicates a greater proportion of ISIC38 production is traded than the other sectors. ISIC31 (Manufacturing of Food, Beverages, and Tobacco) is the second largest sector but its share of trade is half that of its share of production.

In almost every sector, countries that exported more also imported more. Column four gives the correlation between countries' total exports and total imports for 1985 (scaled as a share of their GDP). For instance, in ISIC31 (Food Manufacturing) the correlation between relative size of imports and exports was 0.9090. The positive correlations indicate high two-way trade. The smallest correlation was for ISIC324 (Manufacture Footwear Except Rubber Or Plastic) at -0.0057.

An important question is whether the gravity equation is appropriate for analyzing sectoral trade. Can the simple gravity equation, which works so well for total trade, be extended to partitions of total trade? The monopolistic basis for the gravity model described above says nothing about the volume of trade within arbitrary sectors for a particular country. This is due to the fundamental indeterminacy of the underlying monopolistic model. We cannot say which products are produced where. We can, however, say something about a country's total production and trade.[2]

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[2] There are, of course, alternative specifications that can also generate gravity equations (see Deardorff, 1998, for some examples). Harrigan (1996, pp 25-26) suggests an alternative that permits sector specific gravity equations. From the monopolistic model offered above we have $M^k_{ij} = s_i Y^k_j$. As Harrigan points out, it is possible to express industry outputs as a linear function of country factor endowments with coefficients for each sector the same across countries: $Y_i^k = \beta^k v_i$ where β^k is a vector of coefficients for sector k and v_i is a vector of factor endowments for country i. By substitution we get $M^k_{ij} = s_j \beta^k v_i$. This equation holds for all countries and

TABLE 4.1: ISIC MANUFACTURING INDUSTRIES 1985

3	Manufacturing	PROD Shares	EXPORT Shares	CORR EXP IMP
31	**Manufacturing of Food, Beverages and Tobacco**	**0.158**	**0.088**	**0.9090**
	311 Food manufacturing	0.106	0.071	0.8880
	312 Other food manufacturing	0.021	0.006	0.9237
	313 Beverage industries	0.020	0.008	0.7884
	314 Tobacco manufactures	0.010	0.003	0.6489
32	**Textile, Wearing Apparel and Leather Industries**	**0.072**	**0.075**	**0.4863**
	321 Manufacture of textiles	0.043	0.043	0.7992
	322 Manufacture of wearing apparel except footwear	0.021	0.020	0.0752
	323 Manufacture prods. leather not footwear and	0.003	0.005	0.3461
	324 Manufacture footwear except rubber or plastic	0.005	0.007	-0.0057
33	**Manufacture of Wood and Wood Products**	**0.035**	**0.024**	**0.3343**
	331 Manufacture wood, wood prods; not furniture	0.021	0.017	0.3201
	332 Manufacture furniture, fixtures except primarily	0.014	0.006	0.3770
34	**Manufacture Paper, Paper Prods. Printing,**	**0.072**	**0.042**	**0.7220**
	341 Manufacture of paper and paper products	0.036	0.035	0.7425
	342 Printing, publishing and allied industries	0.037	0.007	0.5680
35	**Manufacture of Chemicals and Chemical Products**	**0.185**	**0.160**	**0.9043**
	351 Manufacture of industrial chemicals	0.052	0.085	0.8686
	352 Manufacture of other chemical products	0.035	0.024	0.8272
	353 Petroleum refineries	0.062	0.031	0.7566
	354 Misc. products of petroleum and coal	0.005	0.004	0.6143
	355 Rubber products	0.011	0.010	0.6627
	356 Plastic products (Not elsewhere classified)	0.019	0.007	0.7661
36	**Manufacture Non-Metallic Mineral Prods. Except**	**0.032**	**0.018**	**0.6800**
	361 Pottery, china and earthware	0.003	0.003	0.0613
	362 Glass and glass products	0.007	0.006	0.7340
	369 Other non-metallic mineral products	0.023	0.009	0.7056
37	**Basic Metal Industries**	**0.083**	**0.095**	**0.9076**
	371 Iron and steel basic industries	0.058	0.065	0.7833
	372 Non-ferrous metal basic industries	0.024	0.030	0.7930
38	**Fabricated Metal Products, Machinery And**	**0.352**	**0.481**	**0.6653**
	380 Metal scrap from fabricated metal prods.	0.000	0.004	
	381 Fabricated metal products, except machinery	0.062	0.034	0.6990
	382 Manufacture of machinery except electrical	0.090	0.152	0.7617
	383 Electrical machinery, apparatus, appliances and	0.072	0.082	0.5492
	384 Transport equipment	0.113	0.180	0.6297
	385 Prof., scientific, measuring and control	0.016	0.029	0.6668
39	**Other Manufacturing Industries**	**0.011**	**0.018**	**0.8284**

Shares are calculated as a fraction of ISIC3 production or trade for 1985. Correlation is between (total exports of country j / GDP of country j) and (total imports of country j / GDP of country j) for each sector in 1985. A positive correlation implies that countries tended to import and export relatively more of goods in that sector in 1985.

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all sectors for which production is positive in each country. Under Factor Price Equalization, and identical relative factor endowments, each country's endowment will be perfectly correlated with their GDP. Hence, we can use Y_i as an instrument for v_i. This yields a sector specific gravity equation where each sector has separate intercepts and slope coefficients.

Despite the weaker theoretical footing, I don't think there is a problem using the gravity equation at the level of disaggregation used in this paper. First, the gravity equation includes factors that we know should matter in any model of trade, whatever the degree of aggregation. Distance as a proxy for transport costs and GDP as a scale factor should always matter.

One problem is whether sectoral gravity equations omit important variables in particular sectors. They probably do. For instance, sectors are likely to differ in economies of scale, transport costs, distribution networks, the ease of identifying product quality, the predominance of intermediate goods sale, and the nature of consumer preferences. This may give countries comparative advantages in one sector or another that are not materially important at the aggregate level. Are these omitted variables likely to bias measured border effects in important ways? They need not. All countries in this sample produce, export, and import goods in all two-digit categories and in all but two three-digit categories (ISIC312 and 380, both small sectors). Also, propensities to import are matched by propensities to export (see **TABLE 4.1** again). Both of these mimic aggregate trade flows. Of course, omitting important sectoral factors will affect the fit of equations. However, this need not bias border estimates in important ways.

A second problem is that arbitrary selection of sectors might generate border effects even in the absence of any aggregate home bias. They may do this. A simple way to see this is to think of a continuum of goods indexed on the interval zero to one in a world with no home biases. In autarchy, each country produces all the goods it consumes. With free trade, no transport costs, and identical preferences, each country specializes in the production of only a fraction of goods but consumes all goods. Now, within a country the distribution of production across arbitrary sectors can be uniformly distributed, skewed, or "lumpy". If the distribution of production is lumpy, then taking a discrete subset of the product space, say the interval zero to one-quarter, means that some countries may have very little production in that subset. Their share of production will be much less then their share of total world income whereas their share of consumption would equal their share of world income. Conversely, other countries would have production in excess of their share of world income but consumption equal to their share. For example, some countries would have

$\int_0^{1/4} M^k_{ij} dk < s_i \int_0^{1/4} Y^k_j \, dk$ even though they have

$\int_0^1 M^k{}_{ij}\, dk = s_i \int_0^1 Y^k_j\, dk$ (or $M_{ij} = s_i\, Y_j$). Countries with a disproportionate measure of production that falls in this interval would be seen to export more than their share. They would have a small measured border effect in this industry. For the remainder of products, indexed from one-quarter to one, these countries would export less than their share. Consequently, a country could exhibit relatively high border effects in some industries and low in others even though, at the aggregate level, there is no border effect at all. This implies two things. First, the relative rankings of sectoral border effects within a country will not be correlated. If a country has a high ratio of external to internal trade in some sectors, it will have a low ratio in other sectors. The converse holds for other countries. Relative rankings would tend to be random, not showing any particular pattern in one country. Second, the correlation of export and import volumes will tend to be zero. Exports will be independent of imports after correcting for country size.

If, on the other hand, the distribution of production was uniform over the commodity space then $\int_0^{1/4} M^k{}_{ij}\, dk = s_i \int_0^{1/4} Y^k_j\, dk = (Y_i\, Y_j/Y_{world})/4$ and the gravity equation holds with only a shift in the intercept term. In this example, the quantity of trade in the interval decreases to 1/4 the level of aggregate trade. The correlations between export volumes and import volumes would be one.

I don't believe the data used in this paper suffer from this "lumpiness" problem. I offer three arguments. First, the extent to which spurious border effects are generated depends on the breadth of commodity classes employed. The problem is more troublesome the smaller the commodity class used.[3] The level of disaggregation used here should not generate problems. The 30 industrial groups analyzed are themselves an aggregate of many distinct commodities. The level of disaggregation possible is to six digits whereas I am only using the three-digit classification. As I'll show, the fit of regressions using sectoral data is quite close to that of aggregate data.

Second, all countries import and export goods in every sector. Further, the more they export the more they tend to import. This was shown in **TABLE 4.1** by the positive correlation between export and import volumes for all sectors save one (ISIC324). At the two-digit level, all correlations were positive with the lowest correlations at 0.3343 for ISIC33 (Manufacture of Wood and Wood Products). This suggests that the core factors of

[3] This problem exists, to some extent, with all empirical exercises to the extent that good trade data is generally restricted to merchandise trade while ignoring trade in services.

distance and scale should dominate sectoral regressions. The regressions that follow support this.

Third, as I'll show, there is a strong correlation of country-specific border effects across industry groups. This indicates that, at least for manufactures, sectoral data seem to replicate aggregate data to a large extent. This is not too surprising since most OECD trade is in manufactures (averaging 80% over the period) and also tends to high intra-industry trade as well.

Caution should be taken when comparing border effects across sectors and across countries. They should be considered indicative of the degree of openness rather than an absolute measure of openness. Nevertheless, I do make direct comparisons in an attempt to identify stylized facts. As a check, I did run regressions with aggregated data as well as disaggregated data with sectoral dummies. Regression results, reported below, were similar so I am confident that the use of subaggregates does not pose a problem.

4.2.3: External and Internal Trading Distances

Trading distances between countries is measured by the Great Circle Distance between their respective economic centers of mass. As is standard in this literature, capital cities are taken as the economic center. An exception is the use of Chicago as the center of the USA. Latitudes and Longitudes are reported in the appendix. An alternative specification is to take a weighted average of the latitudes and longitudes of principal cities with population shares used as weights. Identical regressions were run using this alternative distance measure but there appeared to be little qualitative difference in regressions results. They are not reported.

More importantly, the magnitude of border effects is intimately tied to the measure of internal distances. If the true internal shipping distance is over-estimated, then measured border effects will also be over-estimated by approximately the same proportion since expected internal trade would be small but actual trade large. Doubling of internal distances will approximately double the border effect. The relationship is not exact since the estimated elasticity of trade with respect to distance is slightly less than one.

There appears to be no easy way to get an accurate measure of internal distances. Wei and Helliwell choose internal distances to be 25% of the distance to the nearest neighbor. This would correspond to one-half the radius of a circular country if their closest neighbor is the same size. Wolf (1996) used the minimum driving distance between the two largest cities and, as an alternative, one-half the average distance to all adjacent states. Nitsch, however, (1997) argues quite effectively that a more systematic rule should be employed that relates the land area of a country to its internal distance. He points out that France and Germany are given the same internal distance using Wei's method even though France is twice as large as Germany. Similarly for Spain and Portugal. He recommends that internal distances be calculated as $0.2\sqrt{(\text{country size})}$[4]. As an alternative, he suggests an upper bound of $0.6\sqrt{(\text{country size})}$.

There are other more computationally intense measures that can be used. Head and Mayer (2000) calculate internal distances as a weighted average of distances between sub-regions in a country. They use the share of two-digit industry-level employment as weights of the exporting country and regional GDP shares for the importing country. Chen (2000) calculates a weighted average of distance between major cities within a country using regional GDP shares as weights. Helliwell and Verdier (1999) combine approaches by incorporating the geographic and economic sizes and relative locations of cities and rural areas. The calculated internal distance is a weighted average of intra and inter-city distances, city-rural distances, and intra and inter rural distances. The process captures the degree of urbanization as well as the distribution and density of rural populations in arable regions within a country. The data requirements to complete this process are high. Projects are currently underway to calculte these internal distances

It is clear that more work in this area needs to be done. The primary internal distance method I chose is Wei's as used in Helliwell (1998). My intent is to provide a point of comparison with Helliwell's OECD border estimates since the shipment data used here is different. I do report results using Nitsch's method though it made little difference at the aggregate level. Both internal distance measures are listed in **TABLE 4.2**. The correlation between the two measures is high at 0.77. On average, internal distances rise using Nitsch's method, doubling for Australia, Canada, France, and the USA, but falling significantly for

[4] He arrives at this by calibrating a weighted average of inter-provincial trading distances used by Helliwell (using trade shares as weights) and relating it to the square root of Canada's land area. He should, of course, have used GDP or population as weights rather than actual trade as weights.

Denmark and Portugal. Country-specific border effects using both methods are reported later. Given the lack of a clear measure of internal distance, one is cautioned that comparisons across countries may not be appropriate. It may be an artifact of mis-measured internal distances. Comparisons over time for a country should be fine. Similarly, comparisons across sectors, but within a country, should not be too sensitive to measurement errors.

TABLE 4.2: ECONOMIC CENTERS AND INTERNAL DISTANCES

	LOCATION	LAT	LONG	INTERNAL (Helliwell)	DISTANCES (Nitsch)	RATIO
AUS	SYDNEY	-33.88	151.20	259.03	554.3	2.1
AUT	VIENNA	48.20	16.37	67.53	57.9	0.9
BEL	BRUSSELS	50.83	4.33	43.35	36.4	0.8
CAN	OTTAWA	45.42	-75.70	259.03	631.5	2.4
DEN	COPENHAG	55.67	12.58	130.51	41.5	0.3
FIN	HELSINKI	60.17	24.97	99.55	116.3	1.2
FRA	PARIS	48.87	2.33	65.37	147.5	2.3
GER	BONN	50.73	7.10	65.37	99.7	1.5
GRC	ATHENS	37.98	23.73	92.75	72.7	0.8
IRE	DUBLIN	53.33	-6.25	43.50	53.0	1.2
ITA	ROME	41.90	12.48	173.73	109.8	0.6
JPN	TOKYO	35.70	139.77	173.73	120.3	0.7
NET	AMSTERDA	52.35	4.92	43.35	40.8	0.9
NOR	OSLO	59.92	10.75	103.83	113.8	1.1
NZL	WELLINGT	-41.30	174.78	173.73	104.0	0.6
POR	LISBON	38.72	-9.13	125.80	60.7	0.5
SPN	MADRID	40.40	-3.68	125.80	142.1	1.1
SWE	STOCKHOL	59.33	18.05	99.55	134.2	1.3
TUR	ANKARA	39.93	32.87	92.75	176.6	1.9
UKG	LONDON	51.50	-0.12	85.20	98.8	1.2
USA	CHICAGO	41.88	-87.63	259.03	621.8	2.4
YUG	BELGRADE	44.83	20.50	122.50	108.8	0.9
AVERAGE				117.61	158.38	1.35
CORRELATION				0.835		

Latitude and longnitude are in decimal degrees. Internal distances are in kilometers. Nitsch's internal measure calculated as 0.2 $\sqrt{(km^2)}$. Ratio is Nitsch's measure divided by Helliwell's. COR is between the two internal measures.

4.2.4: Augmented Model

The basic model can be augmented by other factors that are expected to affect trade. We can differentiate these into factors that affect transaction costs, access to markets, and scale effects.

4.2.4.1 Transactions Costs

It is standard practice to introduce variables that measure reductions in the costs of doing business abroad (see for example Frankel 1997, or Feenstra *et al* 1998). Cost reductions may be because of reduced freight costs from shared land borders and mutual access to deep-water ports. Alternately, they can represent factors that reduce the cost of establishing foreign distribution networks such as common language and culture, shared borders, and shared institutions. Or they can be in terms of formal arrangements to reduce barriers to trade such as common membership in economic unions and free trade associations: the lower the cost, the greater the trade.

4.2.4.2 Access To Alternative Markets:

If we take the gravity metaphor seriously, then the location and size of other economic masses will partially determine the flow of goods from one country to another.[5] This is like the phases of the moon affecting tides. In the trade context, this reduces to measuring the availability of alternative markets for each trading pair. The more alternatives a pair has, the less they trade together.

There are a number of ways of formalizing this diversion of trade. The approach I use follows personal communications with Helliwell. It uses the simple gravity equation to calibrate potential trade with other countries. It is a reciprocal analog to the remoteness variable used in Helliwell (1998) which itself differs from Wei's (1996) measure of remoteness. They measured the relative isolation of country, arguing that the more remote a country was from other trading opportunities, the more it would trade with a particular country. Wei's measures are incompatible with the basic gravity equation.

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[5] See Deardorf (1998) for a derivation and discussion.

In this chapter, access to alternative markets is a weighted average of alternative trading opportunities for country x thinking about exporting to country m: the larger the measure, the greater the alternatives to m facing exporters in country x. It is calculated as: $ALT_{x\,m} = \Sigma_j\,(GDP_j/DIST_{x\,j})$ *for all j not equal to m or x*. As $ALT_{x\,m}$ rises, exports from x to m should decrease as the available volume of x's exports are drawn into (diverted to) other markets. Consider, for example, the trading pair New Zealand - Portugal. For New Zealand, Australia is both large and near, so would tend to attract sales away from Portugal as New Zealand firms concentrate on the more attractive (nearer) Australian market.

We can calculate the analog for the importer. Access to alternative import markets is measured as: $ALT_{mx} = \Sigma_j\,(GDP_j/DIST_{m\,j})$ *for all j not equal to m or x*. The more alternatives the importing country has, the less it will import from country x. Consider Portugal and New Zealand again. Portugal is close to the heart of Europe so it would be drawn to look for imports from them rather than from New Zealand.

Together, we expect to see less trade between New Zealand and Portugal than, say, between New Zealand and Australia. Portugal has many nearby alternatives for imports and exports whereas New Zealand, and Australia, do not.

The measure of alternatives changes as the trading partner changes. For instance, $ALT_{CAN\text{-}US}$ is low for Canada since Canadian alternatives to the US are poor. We are far from all other countries in the sample. However, $ALT_{CAN\text{-}AUS}$ is large since the US is so close and so large. **TABLE 4.3** ranks countries by their value of $ALTx$ in 1985. Column two gives a measure $ALT_x = \Sigma\,(GDP_j/DIST_{xj})$ *for all j not equal to x* for 1985. Note that this differs from the above in that it does not exclude any trading partners. Bilateral measures used in regressions are, of course, smaller depending on the partner.

Stein and Weinhold (1998) propose five properties that remoteness measures should satisfy. Helliwell adds one more. The analogue of these properties for a measure of attractiveness is:[6]

1 A measure of attractiveness of a country should decrease with distance to the trading partners.

2. Attractiveness should be independent of the redrawing of borders, except for the effects of the new capital cities, or any effects that the redrawing may cause on total GDP.

[6] See Stewart (1999) for a discussion of these properties and verification that the attractiveness measure satisfies these properties.

3. A measure of attractiveness should be sensitive to the inclusion or exclusion of large countries in the sample.
4. A measure of attractiveness should remain virtually unchanged when a very small country is added to the sample.
5. Other things equal, the growth in a large country should affect the attractiveness measure more than a similar percentage growth of a small country.
6. Attractiveness should increase when any country grows.

TABLE 4.3 shows that the European countries of Belgium, Netherlands, and France have the greatest market alternatives while Australia and New Zealand have the least.

TABLE 4.3: ALTERNATIVE MARKET ACCESS 1985

	ALT[1]	rank	ALTw[2]	rank	ALTh[3]	rank
BEL	11727	1	10566	1	14495	4
NET	9512	2	10211	2	13247	6
FRA	6774	3	6912	6	17605	2
GER	6502	4	7537	4	18408	1
UKG	6436	5	6206	9	13864	5
IRE	5264	6	6650	8	5852	12
DEN	4972	7	7145	5	5508	13
AUT	4819	8	8099	3	6090	10
CAN	4656	9	5122	13	6105	9
NOR	4059	10	5499	12	4687	15
YUG	4028	11	6688	7	4456	17
SWE	3695	12	5807	10	4723	14
SPN	3547	13	4930	14	5921	11
ITA	3487	14	5773	11	7125	8
POR	3449	15	4647	17	3831	18
FIN	3214	16	4740	16	3792	20
GRC	2978	17	4907	15	3823	19
TUR	2355	18	4324	18	4512	16
USA	1094	19	1922	20	16411	3
JPN	878	20	2268	19	8781	7
NZL	766	21	1339	22	945	22
AUS	723	22	1379	21	1417	21
Corr	ALT and ALTw 0.9302					
Corr	ALTand ALTh 0.5757					

1 ALT is calculated as $ALT_x = \Sigma (GDP_j / DIST_{xj})$ *for all j not equal to x.* Countries x and j are from the 22 OECD countries.

2 ALTh is calculated as $ALT_x = \Sigma (GDP_j / DIST_{xj})$ *for all j.* Countries x and j are from the 22 OECD countries.

3 ALTw is calculated as $ALT_x = \Sigma (GDP_j / DIST_{xj})$ *for all j not equal to x.* Countries x and j are from 161 countries in the world.

The measure above uses only the 22 countries in the sample as alternative markets. A different specification would use all countries in the world.[7] The concern here is that Japan, which is isolated from the other 21 countries, actually has many close markets in South East Asia that are ignored in ALT_x. I constructed a new measure, denoted ALTw, where I included 165 of the world's largest economies for which I could find appropriate GDP data. I then isolated the measures for the 22 countries in the sample. The analogs to ALT_x are shown in **TABLE 4.3**, column four. Surprisingly, this didn't seem to matter. The correlation between columns two and four is high at 0.9302. Both measures show that the USA and Japan are relatively remote from markets while European countries are close even after accounting for Latin America and South East Asia. Including all countries in the world did make the US and Japan less remote from potential markets. However, this inclusion of all potential partners did not affect estimated coefficients on alternative markets access appreciably nor did any regression results change qualitatively either. Regression results using this measure are not reported.

Another choice is to include the <u>home</u> market as an alternative market for exporters and importers. I denote this as ALTh. Helliwell's Canadian study employed a variant of this since he used other provinces as potential markets for a province's exports. The idea here is that the US and Japan, which have very large home markets, have many alternatives to external trade: firms can export within the union. This would tend to decrease its exports to all other markets. This measure turns out to make a difference. These new values are presented in column six of **TABLE 4.3**. The correlation between ALT and ALTh is only 0.5757 so will make a difference in the regressions. Notice now that the USA has the 3rd highest value rather than 3rd lowest. Belgium's alternatives hardly change since its home market is small. Estimated coefficients using this measure differed from ALT with Border Effects rising substantially. This is discussed in more detail later. This measure suffers from possible measurement error since it uses Wei's internal distances. If these are under-estimated, then ALTh will be over-estimated.

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[7] The difficulty with this latter measure is the availability of PPP adjusted GDP for some of the smaller countries as well as communist countries. See the data appendix for a description of the data sources used.

4.2.4.3 Population And GDP Per Capita Scale Effects:

The basic gravity equation uses GDP as a scaling factor. Helliwell (1998) notes that population and per capita income may be better scaling factors than GDP alone (pp 47-50). The hypothesis is that, for a given GDP, the bigger the population, the smaller the per capita income and the lower the propensity to trade. This could be because less developed countries have very different consumption preferences from other countries and so find foreign goods less desirable. More developed countries may converge in preferences and so gain by trading. Alternately, less developed countries may lack sufficient infrastructure (i.e. port facilities) or expertise to take advantage of trading opportunities. This would increase transactions costs and so lower trade. They may produce inferior products so find transportation margins difficult to overcome. They may have higher tariffs as a source of government revenues in lieu of income taxes. Or they may suffer combinations of the above.

There are a number of ways of introducing population and per capita income into these regressions. You can use (logged values of) POP and GDP/POP or POP and GDP individually. In the log-linear form, these are equivalent. With POP and GDP entered individually, the estimate on GDP is the same as on a regression with GDP per capita entered with POP. The net difference between the estimate on GDP and on POP is the true scale affect of POP alone on trade. I choose to use POP and GDP entered individually.

In previous work, border coefficients for individual countries appear to fall as per capita income of the country rises (Wei 1996, Nitsch 1997, and Helliwell, 1998). To capture this effect, we can interact per capita income with the dummy on own-trade. I use Helliwell's approach so that my estimates are directly comparable. Helliwell first calculates per capita incomes for each country in each year (PCI) and their geometric mean (PCIm). The log of the ratio (PCIj/PCIm) for country j gives its deviation from average per capita income for that year. He then multiplies this with the dummy on own-trade to get a variable that takes a value of zero for all observations that do not include own-trade. I denote this variable as oPCI. It is expected to have a negative sign; richer countries should have lower borders, all else equal. The dummy variable OWN now refers to the border effect of an average OECD country. We can infer the border effect for any specific country as $BEj = \exp[BE_{OECD} + \ln(PCIj/PCIm)\ oPCI]$ where (PCIj/PCIm) is country j's per capita GDP relative to the OECD mean. BE_{OECD} and oPCI are estimated.

4.2.5 Augmented Gravity Model:

The augmented gravity model using the trade related factors above becomes:

(3)	$ln(S_{x\,m}) = \alpha +$
(scale effects)	$\beta_1 ln(Y_x) + \beta_2 ln(Y_m) + \beta_3 ln(POP_x) + \beta_4 ln(POP_m) +$
(transport costs)	$\chi\, ln(DIST_{xm}) +$
(alternative markets)	$\delta_1\, ln(ALT_{xm}) + \delta_2\, ln(ALT_{mx}) +$
(transaction costs)	$\phi_1 LANG + \phi_2 ADJ + \phi_3 OC + \phi_4 EU70 + \phi_5 EU73 + \phi_6 EU81 +$
(own trade)	$\gamma_2(OWN) + \gamma_2(oPCI) + \varepsilon_{xm}$

The variables **S**, **Y**, **POP**, **DIST** and **ALT** were described above. As were the dummy variables **OWN** and **oPCI**.

LANG and **ADJ** are dummy variables for common language and adjacency. See the appendix for countries that share common languages. **OC** interacts distance with an ocean dummy variable indicating both trading countries share access to deep water ports. Austria is the only landlocked country in the sample. Countries that are near to one another, say Norway and Sweden, are given a value of zero since most trade will not require deep sea access. Norway and Japan would use deep sea ports for much of their trade. See the appendix for the country pairs where the ocean dummy takes on a value of one. We need to interact this dummy with distance since near countries are excluded meaning the ocean dummy alone will be positively correlated to distance and negatively correlated with trade.

The dummy variables beginning with EU are for intra-EU trade and accounts for the different timing of entry of member countries. **EU70** takes a value of one if trade is between the original members of the EU (Belguim-Luxembourg, France, Germany, Italy, and Netherlands) and zero otherwise. **EU73** is for trade between the three new entrants in 1973 (Denmark, Ireland, and United Kingdom) and with the six existing EU members. Similarly for **EU81** with the entrance of Greece in 1981. This specification allows us to test for the degree of integration among EU members and to see whether they differ depending on the timing of entry. For example, we can see whether the density of trade between the United Kingdom, Denmark, and Ireland and the original six EU members is as dense as the trade between the original six. It isn't. I used the dummy for all 16 years, even for the years prior to a country being formally adopted into the union. Frankel (1997) argues that this is appropriate since the degree of economic integration often precedes formal recognition.

An alternative specification would be to use an accumulating dummy that takes a value of one whenever trade is between EU members. This presumes that the density of trade between incoming members is a dense as between existing members. This is unlikely to be true. This is a testable hypothesis.

4.3 AGGREGATE and COUNTRY SPECIFIC BORDER EFFECTS:

This section identifies the average border effects at the aggregate level ISIC3 for each year 1970-85 using equation (3) as the baseline. I also identify and rank country specific border effects at the aggregate level. Results are compared using different internal distance measures and different ALT measures. To save space I report only the results for 1970, 1975, 1980, and 1985.

4.3.1 Trade Data

Bilateral shipment data come from the OECD Compatible Trade and Production (COMTAP) database.[8] There is data on 22 OECD countries: Australia, Austria, Belgium-Luxembourg, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Turkey, United Kingdom, United States, and Yugoslavia. Data covers the period 1970 to 1985.

Production data is provided at the four-digit International Standard Industrial Classification (ISIC), Revision 2, for thirteen of the countries and at the three-digit level for the remaining countries. Only manufacturing goods, starting with ISIC code 3, are included. There are nine two-digit industrial sectors, ISIC31 to ISIC39, comprising 30 separate industries. Each sector has at least two three-digit industries except ISIC39. It has only one industry.

Shipment data, originally reported using the Standard International Trade Classification (SITC), was converted to the ISIC categories for a concordance with production data. Both exports to, and imports from, all countries in the world are reported

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[8] The data is available from the NBER on their "Trade Database Disc 2: World Trade Flows 1970-1992" CD-ROM. Refer to NBER working paper 5910 for a more thorough description of the data used.

for all 22 countries. All values are reported in thousands of US$. I use both three-digit data and aggregated data at the one and two-digit level.

Internal shipments were calculated as the difference between total production and total exports for that particular ISIC category. For some countries, notably the Netherlands and Belgium, internal shipments were negative for some of the three-digit categories indicating exports exceeded production. This probably occurs since entrépot trade (re-export) is not subtracted from gross exports and so raises measured exports above their true levels. This also occurred for a few countries in two-digit categories but never at the aggregate level.

It would have been preferable to use import values rather than export values as import data tend to be more accurately measured. This was not possible. One would require a full bilateral trade matrix among ALL countries in the world. This is not available at the disaggregated level. This need not pose a problem. The use of the export data will tend to underestimate, rather than overestimate, border effects. It does this since own-exports are a residual of production less total exports. Over reporting exports will under report own-trade and so bias border effects downward.[9]

See Appendix III for a description of the other data sources.

4.3.2 Regression Procedures

Two regression techniques were used. First, I ran regressions for each year using pooled data with industry dummies to pick up fixed effects. Each year had a maximum of 14520 observations (30 sectors with a maximum of 484 bilateral pairs in each sector). Skipping observations with either zero trade or negative own-trade reduced this to 11651 in 1970 and 12811 in 1985.

As noted in Section 4.2, however, aggregated shipments may be the more appropriate data to use. So I also ran seemingly unrelated regressions (SUR) on aggregated data for all 16 years. I used unrestricted SUR for two reasons. First, restricting coefficients to be the same over the 16 years seldom passed a formal F-test. Second, I wanted to show how non-border coefficients varied over time to gain some understanding of the trade dynamics that were taking place over this period.

[9] I did test whether replacing export values with their corresponding import values changed estimates in a basic gravity equation without own-trade. It didn't. Estimated coefficients were identical to three digits.

Observations with zero trade were omitted from the SUR regressions. This reduced observations from 484 to 481. There were no observations of negative own trade at the aggregate level.[10]

As it turns out, however, the SUR regressions at the aggregate and subaggregate levels generated almost identical border coefficients as the pooled sample. To save space I report results for average OECD border effects using SUR regressions.

One potential difficulty with SUR regressions is that there is only one observation of own-trade per country per year for aggregates. There are 22 observations of own-trade per year. This is sufficient for finding average OECD border effects. I had some concerns that this was not sufficient for finding country-specific effects since there is only one observation per country per year. However, one can estimate country-specific border effects (as per Wei and Nitsch) by pooling observations over time. As will be shown, however, border effects are falling throughout the period so pooling over time is inappropriate. In each year though, there are up to 30 observations of own-trade per country at the disaggregated level. Pooling across industries, and accounting for industry fixed effects, allows one to get precise country-specific estimates for each year. As it turned out, this was unnecessary. As in the aggregate case, estimated border coefficients using SUR regressions were very similar to those from the pooled sample where I used country fixed effects for own-trade. This should not have been surprising since the volume of trade within a country relative to external trade is often orders of magnitude larger. Hence, even one observation of own-trade will often be significant. I found it reassuring that the two approaches yielded very similar results. To save space I report only results from the SUR regressions.

[10] For individual three-digit sectors the number of zero observations rises significantly. One way to accommodate the information contained in those observations is to use Heckman's two-step (Heckit) procedure. The problem with that approach is that the standard errors need to be corrected so requires each equation to be run separately. This loses some of the cross equation information captured in the SUR regressions. I compared border effects from individual Heckit regression to those from individual OLS regressions. In 48% of the regressions the Heckit regression gave a higher border estimate than the corresponding OLS regression. This suggests that the Heckit procedure does not justify the loss in information from abandoning the SUR regressions.

4.3.3: ISIC3 Aggregate Manufacturing

I ran unrestricted SUR regression for equation (3) from 1970 to 1985 using aggregate data for ISIC3. **TABLE 4.4a** shows results for 1970, 1975, 1980, and 1985. The measured border effect is calculated as exp(OWN). T-statistics are reported below each estimated coefficient.

A few comments are in order. First, the fit of these equations is high, confirming the strong empirical performance of gravity models. These are not as high as those reported by Helliwell and Nitsch.

There were no real surprises in the size, or signs, of coefficients.

The elasticity of exports with respect to the exporter's GDP per capita is larger than one as expected. It is larger than the importer's elasticity for all but the last three years. However, in 1983 the exporters' elasticity fell below the importers'. The importer's elasticity was relatively constant over the period. Regressions omitting population showed the same patterns on GDP alone. It declined slightly for the exporter while increasing for the importer. I cannot say why the switch occurred.

The elasticity with respect to population was negative as expected.

The effect of distance on trade is negative and highly significant. The ocean (OC) and adjacency variables are always positive but seldom significant. The language variable was always positive taking a value of 1 in 1970 but declining to about 0.76 by 1985. This means that countries that shared the same language traded about twice as much as otherwise identical trading pairs. Trade flows were much stronger between the original members of the EU than newer members suggesting a much deeper level of integration. The 1973 entrants, however, had approached a similar degree of integration by 1985. The EU dummy for Greece's entry, however, are sometimes negative (but not statistically significant) at the beginning of the period. This indicates that trade between Greece and the other EU members was lower than expected given distance, economic size, and proximity. By 1985, however, Greece appeared to be fully integrated into the EU.

TABLE 4.4a: SUR regressions ISIC3

	1970	1975	1980	1985
R^2	0.8162	0.8277	0.8362	0.8095
LGDPx	1.5028 18.45	1.6096 19.83	1.5551 20.13	0.8743 13.21
LGDPm	1.1569 14.26	1.2552 15.52	1.2838 16.66	1.1497 17.51
LPOPx	-0.7574 -8.07	-0.8774 -9.50	-0.8466 -9.56	-0.1284 -1.64
LPOPm	-0.5127 -5.49	-0.5919 -6.44	-0.6479 -7.34	-0.4433 -5.71
LDIST	-0.8612 -10.10	-1.0104 -12.38	-0.9655 -12.31	-0.9640 -12.04
LALTx	-0.0778 -0.94	-0.0807 -1.01	-0.1020 -1.32	-0.0386 -0.48
LALTm	-0.0900 -1.09	-0.1714 -2.14	-0.1336 -1.72	-0.2958 -3.69
LANG	1.0963 5.69	0.9154 4.99	0.9833 5.58	0.7651 4.21
ADJ	0.4068 1.55	0.1240 0.50	0.2918 1.21	0.2510 1.01
OC	0.0310 1.29	0.0463 2.02	0.0396 1.80	0.0320 1.41
EU70	0.4831 1.58	0.6235 2.15	0.5869 2.10	0.4906 1.70
EU73	-0.2844 -1.34	0.1222 0.61	0.4090 2.11	0.3549 1.77
EU81	-0.1017 -0.36	0.2460 0.92	0.5127 1.99	0.2906 1.10
OWN	3.3980 9.61	2.8940 8.55	2.8724 8.81	2.2798 6.83
OPCI	-1.5229 -4.13	-1.9100 -5.20	-2.0098 -5.75	-1.2629 -4.19
CONST	2.2586 1.37	3.1936 1.93	2.6536 1.59	3.7657 2.14
BE	**29.9**	**18.1**	**17.7**	**9.8**
BE if rich	**18.9**	**10.2**	**9.7**	**6.7**

t-statistics are reported under each estimate. Border effect is calculated as exp(OWN). The border effect for a rich country (per capita income twice the mean) is calculated as: BE rich = exp([OWN + ln (2) oPCI].

TABLE 4.4b: SUR ISIC3 using ALTh

	1970	1975	1980	1985
R^2	0.8161	0.8274	0.8348	0.8108
LGDPx	1.4982 17.22	1.5551 18.13	1.4959 18.12	0.7751 10.96
LGDPm	1.1547 13.33	1.2674 14.83	1.2615 15.33	1.1967 17.05
LPOPx	-0.7696 -8.24	-0.8842 -9.62	-0.8456 -9.59	-0.1473 -1.90
LPOPm	-0.4984 -5.36	-0.5652 -6.18	-0.6224 -7.09	-0.4016 -5.21
LDIST	-0.7767 -9.76	-0.8728 -11.56	-0.8085 -11.16	-0.7871 -10.66
LALThx	0.0776 0.80	0.2007 2.16	0.2006 2.23	0.3423 3.70
LALThm	-0.0045 -0.05	-0.0549 -0.59	0.0381 0.42	-0.1526 -1.65
LANG	1.1050 5.73	0.9371 5.10	1.0107 5.71	0.7915 4.37
ADJ	0.5117 1.97	0.2912 1.17	0.4833 2.01	0.4655 1.90
OC	0.0283 1.18	0.0420 1.84	0.0350 1.58	0.0263 1.16
EU70	0.3854 1.27	0.4774 1.65	0.4236 1.51	0.3048 1.06
EU73	-0.3021 -1.42	0.0972 0.48	0.3786 1.94	0.3262 1.63
EU81	-0.1253 -0.45	0.2004 0.75	0.4552 1.76	0.2345 0.89
OWN	3.6904 9.58	3.3880 9.20	3.4788 9.79	2.9146 8.06
oPCI	-1.5220 -4.08	-1.8624 -5.02	-1.9024 -5.39	-1.1990 -3.96
CONST	-0.0179 -0.02	-0.5768 -0.49	-1.7157 -1.44	-1.5713 -1.27
BE	**40.1**	**29.6**	**32.4**	**18.4**
BE if rich	**25.3**	**16.9**	**18.3**	**12.9**

An interesting result was that ALTx tended to be less negative than ALTm. It appears that the exporter's proximity to alternative markets had much less effect on the volume of trade whereas it had a strong negative effect for the importer. This suggests that access to larger export markets may be enhancing the competitive position of firms or increasing the pressure to specialize in product lines. The effect appeared to become stronger over the period. This is discussed in more detail with the sectoral regressions.

Many of the patterns above carried through to the subaggregates as well.

The measured border effects for an average OECD country began at 29.9 and fell to 9.8 in 1985, a decline of two-thirds. This means that countries traded from 10 to 30 times as much with themselves as they did with an otherwise identical country. The value fell in every year except 1975,1976 and 1978[11]. The value of 9.8 for 1985 is within one standard error of the 10.4 reported by Helliwell for 1988 for merchandise trade within the OECD.

Per capita income was negatively correlated with border effects as expected. The estimate on oPCI was negative and large. For instance, a country that had twice the per capita income of an average OECD country had a border effect beginning at 18 and falling to 6.7.[12] This is compared to the values 30 and 10 for the average.

One measure of the importance of per capita income is to ask how much of the secular decline in the measured border effect from 1970 to 1985 can be attributed solely to the increase in per capita income, and associated institutional arrangements, of the sample countries over the period. To find this decomposition we can impute the border effect that *would result* if we take the average per capita income for 1985 and calculate the border effect using oPCI for 1970. However, the estimate for oPCI was taken across the sample countries. Differences across countries in GDP per capita (at PPP values) are real differences in consumption possibilities. Over time though, much of the rise in per capita income is purely

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[11] An interesting artifact is that, from 1974 to 1980, there seemed to be no real decline in Border Effects. Also, the density of EU trade rose relative to average OECD trade as did the elasticity of exporters' per capita income. This was concurrent to the oil shocks of the 1970s. It might be that the oil shock and subsequent recession induced business contractions to fall disproportionately on foreign sales or on recently embraced partners. Firms might have retrenched by focusing on long-term, historical relationships at the expense of newer relationships. This was not the case, however, in the early 1980s. We would need a longer data series to say more.

[12] This is calculated as $BE = \exp([BE_{OECD} + \ln(PCI/PCIm)\ oPCI])$ where $PCI/PCIm = 2$.

nominal. Since all GDPs are measured relative to the US$, we can deflate all the GDP values by the US GDP deflator. In nominal terms, the mean per capita income in 1970 was $2445 and rose to $9375. This is a rise of 350 percent. In real terms however, using 1980 as a base, real per capita incomes rose from $5414 to $7306. A rise of only 35 percent

If we use the data for 1970 from TABLE 4.4a and calculate the expected border effect of a country with 1.35 times the mean per capita income for 1970 we get a border effect of 18.95.[13] This is higher than the observed average border effect of 9.8 in 1985. If we work backwards using 1985 data we get a border effect for 1970 of 14.27.

An alternative is to restrict all the coefficients in the SUR regression, except the coefficient on OWN, to be constant over the sixteen years. This yields a border effect in 1970 of 24.75, 10.93 in 1985, and oPCI of –0.83495. This generates an imputed 1985 border effect of 19.27 or an imputed 1970 border effect of 14.04.

In each of these experiments the measured decrease in border effects was less than the actual (estimated) decrease. It appears that the secular rise in per capita incomes can account for about one-third to one-half the total fall in estimated border effects.

Results using Nitsch's internal distance method are almost identical so are not reported.[14] Country-specific border effects change (reported later) but average border effects rise only slightly. Similarly, SUR regressions using ALTw gave similar results to the above so are not reported. This is not the case with ALTh. **TABLE 4.4b** shows SUR regressions using ALTh. Inclusion of the home market in the measure of alternative markets improves the fit of the regressions only marginally for the last three years. There are now two distinct differences between these results and the SUR regressions using ALT. First, the coefficients on $ALTh_x$ are positive for every year and significant after 1974. Coefficients for $ALTh_m$ are negative 13 of 16 times though never significantly different from zero. This suggests that the more alternatives an exporter has access to, the more it trades. This is not so for the importer. This is a much stronger effect than noted above for ALT. Though these results seem contrary to expectations, they are consistent with evidence of a home market advantage. The hypothesis there is that producers with relatively large home markets achieve

[13] This is calculated as $BE = \exp([BE_{OECD} + \ln(PCI/PCIm)\ oPCI])$ where $PCI/PCIm = 1.35$ and oPCI and BE_{OECD} are the 1970 values from TABLE 4.4a.

[14] I used Nitsch's lower bound of $(0.2\sqrt{area})$ rather than $(0.6\sqrt{area})$.

international comparative advantages and so become exporters (see Weder 1998). The positive coefficient on $ALTh_x$ give a similar story: the better the access to markets, the more the country engages in exports. The notion of a home market advantage should be augmented to include proximity to foreign markets as well.

Border effects more than doubled using ALTh. This is partly driven by the positive coefficients on the exporter's access to alternative markets. To see this, note that all observations with internal trade are the same using ALT or ALTh. Observations of external trade, however, have higher values with ALTh since they include the home market as an alternative. The positive coefficient on $ALTh_x$ from the regression indicates relatively more external sales should occur under ALTh than under ALT, all things equal. This raises the home bias under ALTh. This is despite a decrease in the sensitivity to distance. A caution is necessary since results using ALTh may be sensitive to mis-measurement in internal distances. As mentioned, more research in measuring internal distance would be valuable in this confirming these results.

4.3.4: Country Specific Border Effects ISIC3

This section identifies country-specific border effects for each of the 22 OECD countries for each year 1970-85. I use SUR regressions and country specific own-trade dummies to allocate the average OECD home bias amongst countries. I also remove the per capita income variable oPCI.

TABLES 4.5a and **4.5b** show the estimated border coefficient for ISIC3 using both Helliwell's and Nitsch's internal distance measure. Both use equation (3) as the baseline regression. I only report these for 1970, 1975, 1980, and 1985. Results here are broadly consistent with Helliwell's and Nitsch's. Using Helliwell's internal distance measure, we can allocate the countries into four broad categories (for 1985). There are five countries, all EU members, with border effects that are not significantly different from zero at the five percent level: BEL, FRA, GER, NET, and the UKG. Note that this is even though intra-EU trade and adjacency are accounted for. The second group have significant, but still relatively low borders (below 20),: AUS, AUT, CAN, ITA, IRE, DEN, JPN, NOR, SPN, SWE, and the USA. The third group has higher borders: FIN, GRC, NZL, POR and TUR. The last group has very high borders and consists of only YUG.

TABLE 4.5a: COUNTRY SPECIFIC BORDER EFFECTS using HELLIWELL's INTERNAL DISTANCES

	1970	1975	1980	1985
BEL	6	3*	2*	0*
NET	6	4*	4*	2*
GER	9	5*	5*	3*
FRA	10	5*	6	4*
UKG	18	10	10	5*
USA	11	6*	7	7
ITA	28	14	11	7
IRE	59	38	36	10
JPN	28	13	15	11
AUT	25	15	15	12
DEN	20	13	15	12
NOR	33	20	12	13
SPN	22	19	26	13
SWE	30	17	20	14
CAN	28	14	12	18
AUS	42	24	25	20
TUR	104	82	107	22
FIN	39	23	25	24
POR	69	67	63	28
NZL	52	33	42	34
GRC	153	107	108	45
YUG	458	257	174	176

Ranked by border effect in 1985.* denotes estimates that are not significantly different from zero.

TABLE 4.5b: COUNTRY SPECIFIC BORDER EFFECTS using NITSCH's INTERNAL DISTANCES.

	1970	1975	1980	1985
BEL	5*	3*	2*	0*
NET	6*	3*	3*	2*
GER	13	7	7	4*
DEN	8	5*	5*	4*
ITA	19	9	7	5*
UKG	22	12	12	6
JPN	21	9	11	8
FRA	20	12	13	8
IRE	55	35	34	9
AUT	25	14	15	11
NOR	37	22	14	14
POR	37	33	32	14
SPN	25	22	29	15
USA	23	14	16	15
GRC	65	39	41	17
SWE	39	24	27	19
TUR	93	72	95	19
NZL	35	21	27	22
FIN	45	27	29	28
CAN	59	35	29	43
AUS	83	54	53	43
YUG	418	231	157	159

Border effects taken from Unrestricted SUR regressions using (lnGDP, lnPOP, lnDIST, lnALT, LANG, ADJ, OC, EU70, EU73, EU81, and o###) where o### refers to the dummy variable for own-trade within country ###. Calculated as exp(o###).

All countries saw their border effects fall though at slightly different rates. Canada, Denmark, Finland and New Zealand had the smallest declines of about 36% while the Belgium's fell to zero over the sixteen years.

Nitsch's internal distances changed the measured border effects as well as the groupings. This is reported in **TABLE 4.5b**. Not surprisingly, the countries with increases in internal distances saw an increase in their border effect with the reverse for countries with lower internal distances. Australia, Canada, France, and the USA had a doubling of their border effects. They also had a doubling of internal distances. Canada and Australia now become relatively closed while Denmark's border effect is now insignificant from zero. This is consistent with its internal distance falling by 70%.

We can provide a check of the country-specific Border Effects by comparing them to changes in the ratio of total exports to GDP. Changes in this ratio should reflect changes in each country's Border Effect as most variables used in the regression are non-time varying. **TABLE 4.5c** shows each country's X/GDP ratio and Border Effect for 1970 and 1985. The (geometric) average of the ratio of total exports to GDP rose from 11.4 percent to 18.5 percent. This is a rise of 62 per cent over the period. The (geometric) average Border Effect fell (in logs) from 3.36 to 2.34 or 28.8 to 10.4 in levels. Hence, the 1985 Border Effect is only 70 percent of the 1970 value in log terms and 36 per cent in level terms. The rise in exports to GDP is mirrored by a similar decrease in measured Border Effect.

TABLE 4.5c: COUNTRY SPECIFIC EXPORT RATIOS AND BORDER EFFECTS

	TOTAL EXPORTS/GDP (in per cent)			BORDER EFFECT (in logs)		
EXP	1970	1985	ratio	1970	1985	ratio
AUS	10.4	13.0	1.24	3.738	3.018	1.24
AUT	13.8	21.5	1.55	3.235	2.467	1.31
BEL	35.3	47.3	1.34			
CAN	19.5	25.4	1.30	3.318	2.909	1.14
DEN	17.2	25.5	1.48	2.974	2.509	1.19
FIN	16.8	25.1	1.49	3.659	3.181	1.15
FRA	10.3	14.6	1.41	2.307	1.314	1.76
GER	16.3	25.1	1.54	2.164	1.025	2.11
GRC	5.0	8.5	1.68	5.029	3.808	1.32
IRE	18.3	43.0	2.35	4.077	2.305	1.77
ITA	9.3	13.3	1.42	3.329	1.980	1.68
JPN	6.9	13.6	1.97	3.331	2.366	1.41
NET	28.5	47.3	1.66	1.837	0.624	2.95
NOR	30.2	65.4	2.17	3.511	2.532	1.39
NZL	9.5	9.4	0.98	3.949	3.530	1.12
POR	8.1	12.7	1.57	4.231	3.339	1.27
SPN	3.2	8.6	2.74	3.099	2.579	1.20
SWE	23.6	31.5	1.34	3.400	2.626	1.29
TUR	1.9	5.2	2.80	4.645	3.093	1.50
UKG	11.6	17.9	1.55	2.900	1.585	1.83
USA	4.6	5.9	1.27	2.382	1.874	1.27
YUG	11.7	25.4	2.17	6.127	5.170	1.19
Mean	11.35	18.46	1.63	3.357	2.341	1.43

Total exports are for all merchandise trade. GDP is in PPP values. Mean refers to geometric mean. Belgium was omitted since her Border effect in 1985 was negative (in logs).

4.4 SECTORAL and INDUSTRY SPECIFIC BORDER EFFECTS:

This section identifies border effects for the average OECD country for each of eight major sectors and twenty-eight industries. I also identify country-specific, sectoral effects. Identifying individual border effects across industries is important. First, it identifies which industries can be considered very export orientated and which are focused primarily on domestic markets. This has policy implications since the degree of export orientation may tell us which industries are more sensitive to trade policies. For instance, it might tell us which industries are likely to be sensitive to exchange rate variability. It may also tell us which industries are likely to be transformed with the creation of economic unions and free-trade associations. For instance, if an industry is purely focused on domestic markets, then economic unions may initiate a great deal of reorganization within previously domestic industries. Industries already very open to trade may see little differences before and after a union. An example might be the high degree of integration in automotive production between Canada and the USA. A union of our two countries is unlikely to affect this relationship. However, food production tends to focus exclusively on domestic sales. An economic union might force massive reallocation of production as firms adapt to the larger markets.

Second, identifying individual border effects may give us a measure of the importance of trading barriers within OECD industries and so focus policy attention on those industries that remain relatively closed. Alternately, it may give an indication of different levels of optimal border effects across industries that reflect industry specific characteristics.

4.4.1 Sectoral and Industry Border Effects

Individual unrestricted SUR regressions were run for each of twenty-eight industries and nine sectors using the baseline gravity equation (3). ISIC380 (Scrap Metal) was excluded since measured own trade for all countries was negative. This also occurred in some other industries but to a much lesser extent. To save space, I report the estimates for the OECD average border effects for each of the industries. This is **TABLE 4.6a**. These are summarized for 1970, 1975, 1980, and 1985. I also report coefficients for GDP, distance, and alternative market access, at the aggregate and subaggregate level in **TABLES 4.6b** to **4.6d**. Pooled results and use of Nitsch's distance measure gave very similar results so are not reported.

The fit of sectoral and industry regressions was not as high as for the aggregate. This was partly due to smaller sample sizes but also because of sector-specific omitted variables. Still, the r^2 never fell below 0.5488 for any sector in 1985. **TABLE 4.6a** shows the sample size for the SUR regressions and the r^2 for each industry in 1985. The fit for each system of equations (not reported) was almost always above 0.90. The fit for each equation in 1970 was within 0.08 of that for 1985.

In all, the gravity equation for each industry was able to explain a majority of the variation in bilateral trade flows. The estimated average OECD border coefficients were precisely estimated. The relatively good fit of the equations seems to validate the use of gravity equations.

Sectors can be characterized as having high, medium, or low border effects. The highest border effects were in ISIC311, 312, 313, and 314 (Food, Beverages and Tobacco) with internal trade more than 150 times that of external trade. One might also include in this category ISIC342 (Printing and Publishing) and ISIC 369 (Other Non-Metallic Mineral Products) whose border effects were in excess of 73 and 35 respectively in 1985. These values are high even though the regressions account for the distances involved while the elasticities with respect to distance do not appear too low. Perhaps these results should not be too surprising since food and published products would tend to reflect idiosyncratic national preferences that would not travel well.

TABLE 4.6a: SECTORAL and INDUSTRY BORDER EFFECTS

ISIC	DESC	N =	R^2	1970	1975	1980	1985
3	**MANUFACTURING**	**481**	**0.8095**	**29.9**	**18.1**	**17.7**	**9.8**
31	**FOOD, BEVERAGES, AND TOBACCO**	458	0.7606	**336**	**338**	**291**	**218**
311	food manufacturing	450	0.7525	284	275	216	185
312	other food manufacturing	336	0.7779	205	118	231	159
313	beverage industries	338	0.6861	628	563	359	315
314	tobacco manufactures	179	0.6576	854	646	445	475
32	**TEXTILE, APPAREL AND LEATHER**	**462**	**0.6720**	**41.4**	**21.0**	**13.3**	**7.0**
321	manufacture of textiles	447	0.6551	70.0	35.9	27.2	20.5
322	manufacture of wearing apparel	389	0.6715	23.8	10.4	3.8	1.3*
323	manufacture of leather products	347	0.6283	18.5	16.2	7.1	3.7
324	manufacture of footwear	282	0.5488	29.4	17.1	8.4	4.3
33	**WOOD AND WOOD PRODUCTS**	392	0.7223	23.4	11.4	14.1	11.0
331	manufacture wood, wood and cork	368	0.6431	18.9	9.7	12.2	8.7
332	manufacture furniture, fixtures	334	0.7705	69.6	26.5	20.6	19.5
34	**PAPER PRODUCTS, PRINTING , PUB**	**400**	**0.6708**	**15.6**	**13.0**	**13.5**	**8.8**
341	manufacture paper and paper	365	0.5896	15.1	11.1	10.8	6.4
342	Printing, publishing, and allied ind	372	0.8160	99	113	92	73
35	**CHEMICALS AND CHEMICAL PRODS**	**457**	**0.8084**	**20.8**	**14.8**	**15.2**	**8.5**
351	manufacture of industrial chemicals	423	0.7682	9.0	11.0	9.1	3.6
352	manufacture of other chemical prod	403	0.6926	92.0	39.0	36.2	24.7
353	petroleum refineries	261	0.6528	14.3	31.2	13.9	20.2
354	misc. products of petroleum and coal	259	0.6892	19.6	20.9	10.7	8.1
355	Rubber products	344	0.7660	19.2	8.9	8.1	4.8
356	plastic products n.e.c.	374	0.7893	29.4	19.2	15.7	10.5
36	**NON-METALLIC MINERAL (not fuel)**	**407**	**0.7566**	**40.1**	**31.1**	**20.5**	**18.6**
361	pottery, china, and earthware	305	0.7147	70.1	55.0	24.5	20.6
362	glass and glass products	350	0.7128	30.1	19.6	9.8	11.3
369	other non-metallic mineral products	358	0.7816	51.1	46.8	36.1	35.1
37	**BASIC METAL INDUSTRIES**	**394**	**0.6859**	**15.3**	**5.7**	**4.7**	**2.7**
371	Iron and steel basic industries	357	0.6692	7.9	4.3	2.8	1.6*
372	Non-ferrous metal basic industries	357	0.6538	15.1	11.1	5.6	3.2
38	**FABRICATED METAL PRODS**	**458**	**0.7660**	**14.2**	**8.4**	**8.5**	**5.0**
380	metal scrap						
381	fabricated metal products	428	0.8084	25.8	12.6	12.4	9.9
382	manufacture of machinery	431	0.7440	5.6	4.6	4.6	2.3
383	electrical machinery	414	0.7223	7.4	4.7	5.3	2.7
384	transport equipment	390	0.7473	3.9	3.0	2.9	1.8*
385	Professional scientific, measuring,	398	0.6950	11.4	6.9	3.4	1.6*
39	**OTHER MANUFACTURING**	**407**	**0.7116**	**22.9**	**19.3**	**16.9**	**11.4**

Border effects taken from Unrestricted SUR regressions using (lnGDP, lnPOP, lnDIST, lnALT, LANG, ADJ, OC, EU70, EU73, EU81, OWN, and oPCI) on individual sectors. Calculated as exp(OWN).* denotes estimates that are not significantly different from zero. R^2 is for 1985 only.

TABLE 4.6b: GDP PER CAPITA COEFFICIENTS

ISIC	DESC		1970	1975	1980	1985
3	**Manufacturing**	GDPx	1.50	1.61	1.56	0.87
		GDP	1.16	1.26	1.28	1.15
31	Food, Beverages, and Tobacco	GDPx	1.07	1.21	1.25	0.76
		GDP	1.09	0.98	1.12	0.90
32	Textile, Wearing Apparel and Leather Industries	GDPx	0.90	0.85	0.91	0.26
		GDP	1.52	1.71	1.68	1.37
33	Manufacture Wood and Wood Products	GDPx	0.28*	0.26*	0.46	0.26
		GDP	1.52	1.86	2.15	1.80
34	Manufacture Paper Products, Printing, Publishing	GDPx	0.96	1.05	1.18	0.63
		GDP	0.90	1.03	1.33	1.34
35	Manufacture of Chemicals and Chemical Products	GDPx	1.92	2.02	2.19	1.20
		GDP	1.18	1.23	1.26	1.24
36	**Manufacture Non-Metallic Mineral (not Fuel)**	GDPx	1.20	0.99	1.09	0.29
		GDP	1.35	1.50	1.54	1.37
37	Basic Metal Industries	GDPx	0.98	0.98	1.09	0.48
		GDP	0.90	1.01	1.22	1.04
38	Fabricated Metal prods., Machinery and Equipment	GDPx	2.12	2.13	2.10	1.23
		GDP	1.09	1.30	1.41	1.19
39	Other Manufacturing Industries	GDPx	1.40	1.43	1.85	1.02
		GDP	1.65	1.77	2.07	1.49

All coefficients were statistically significant except for the two denoted with * in ISIC 33

TABLE 4.6c: DIST COEFFICIENTS

ISIC	DESC	1970	1975	1980	1985
3	**Manufacturing**	-0.86	-1.01	-0.97	-0.96
31	Food, Beverages, and Tobacco	-0.59	-0.57	-0.62	-0.67
32	Textile, Wearing Apparel and Leather Industries	-0.70	-0.84	-0.90	-0.94
33	Manufacture Wood and Wood Products	-1.40	-1.49	-1.42	-1.41
34	Manufacture Paper Products, Printing, Publishing	-1.33	-1.36	-1.30	-1.33
35	Manufacture of Chemicals and Chemical Products	-1.13	-1.21	-1.23	-1.23
36	**Manufacture Non-Metallic Mineral prods.(not Fuel)**	-0.96	-1.01	-1.06	-1.04
37	Basic Metal Industries	-0.92	-1.26	-1.23	-1.33
38	Fabricated Metal prods., Machinery and Equipment	-1.06	-1.14	-1.08	-1.09
39	Other Manufacturing Industries	-0.59	-0.59	-0.67	-0.69

All coefficients were statistically significant

Industries with a measured border effect indistinguishable from zero (for 1985) were ISIC322 (Wearing Apparel except Footwear), 371 (Iron and Basic Steel), 384 (Transport Equipment), and 385 (Professional, Scientific, Measuring, and Control Equipment). Firms in these industries did not appear to treat domestic and foreign markets differently.

The remaining industries had statistically significant border effects indicating some tendency to produce for home consumption.

Most industries saw a continual and rapid decrease in border effects over the entire period. ISIC353 (Petroleum Refineries) was the only industry that had a higher border effect in 1985 than in 1970. It did fall as low as 7.2 in 1981 and reached a peak in 1974 with a 300% rise over its 1970 value. The 1985 value is lower than 1974's by 43%. ISIC312 (Other Food Manufacturing) had the smallest decrease of 22% over the period with it too reaching a peak in 1980.

As expected, there were many differences in the other estimated coefficients across sectors. GDP per capita elasticities ranged from a low of 0.26 in ISIC33 to highs of 1.23 in ISIC38 for 1985. The sensitivity to exporters' GDP per capita was lower than importers' GDP per capita in virtually all sectors except ISIC38 (Fabricated Metal, Machinery, and Equipment). This sector included automobiles, airplanes, and computers. As in the aggregate, trade elasticities with respect to exporters' GDP per capita tended to fall over the period while that for importers' tended to rise. This meant that the two changed ranking by 1985 for the aggregate.

Coefficients on distance were always significantly negative in all sectors in all years. The elasticities of trade with respect to distance rose for the aggregate and all subaggregates over the entire period. It fell from 1970 to 1985 in only two industries, ISIC312 and 313, though by less than one standard error. It fell for all subaggregates in the mid 1970's perhaps reflecting the shock to oil prices. It appears that, at the same time that countries are focusing economic activity outward, international trade is becoming more sensitive to the trading distances involved. Frankel (1997) gets a similar pattern using total merchandise trade and a larger number of countries (pp. 62-63). At first glance this result appears odd since transportation costs appear to have fallen, and continued to fall, over this period. Eichengreen and Irwin (1998), however, point out that the rise in the distance coefficient should be interpreted, not as an increase in transport costs, but as a change in the relative costs of transportation between short and long haul distances (p. 43). A uniform decrease in transport costs would have no effect on the estimated coefficients but would show up in a time trend. The bias in transport costs in favour of short hauls would create the rise in the distance coefficient. The log-linear model specification, however, implies a constant elasticity so would be inconsistent with differential cost decreases. As a test I constructed a dummy variable for short distances (dDIST) that took a value of one if the distance was less than 2000 kilometers. This accounted for 220 of the 481 observations. Results from the basic SUR regression including dDIST showed that the elasticity of trade with respect to distance was much lower (-0.6710 in 1985) and the coefficient on dDIST was significantly positive at 0.9601 (in 1985). It appears that trade almost doubles over shorter distances even when accounting for adjacency and internal trade. This supports Eichengreen and Irwin's claim. The greater sensitivity of trade to short distance means that the border effect should rise since internal trade is, by definition, carried out over relatively short distances. This is indeed the case. The measured border effects are higher over the entire period with the 1970 level at 55.01 and falling to 16.98 in 1985.

At the aggregate level, ALTx was insignificantly different from zero while and ALTm was significantly negative in most years. In four of eight subaggregates (ISIC35, 36, 38, and 39), however, the coefficient for ALTx was positive, significantly so in most years, while negative for ALTm. The coefficients and t-statistics are reported in **TABLE 4.6d**. The other sectors generally followed this pattern but to a much weaker extent. Only in sector ISIC31 was the pattern reversed. Here ALTm was positive for half the years. This asymmetry points to a difference in how proximity affects export and import behaviour. Total exports of a country seem to rise as the exporting country gains access to larger alternative markets. It falls as the importer gains access to larger alternative markets. This appears consistent with research that has found some evidence that a relatively large home market leads to comparative advantages and greater exports (Weder, 1998).

TABLE 4.6d: ALT COEFFICIENTS

ISIC	DESC		1970	1975	1980	1985
3	Manufacturing	ALTx	-0.08*	-0.08*	-0.10*	-0.04*
		ALTm	-0.09*	-0.17	-0.13*	-0.30
31	Food, Beverages, and Tobacco	ALTx	-0.37	-0.24	-0.15	-0.10
		ALTm	0.17*	-0.02*	0.02*	-0.17*
32	Textile, Wearing Apparel and Leather Industries	ALTx	-0.04*	0.03*	-0.14*	-0.06*
		ALTm	-0.13*	-0.08*	-0.06*	-0.23
33	Manufacture Wood and Wood Products	ALTx	-0.32	-0.27	-0.45	-0.05
		ALTm	-0.13*	-0.21*	-0.01*	-0.33
34	Manufacture Paper Products, Printing, Publishing	ALTx	-0.11*	-0.10*	-0.25	-0.08*
		ALTm	-0.26	-0.20	-0.28	-0.45
35	Manufacture of Chemicals and Chemical Products	ALTx	0.17	0.17	0.18	0.37
		ALTm	-0.35	-0.39	-0.37	-0.51
36	Manufacture Non-Metallic Mineral prods.(not Fuel)	ALTx	0.24	0.20	0.09*	0.25
		ALTm	-0.56	-0.60	-0.48	-0.67
37	Basic Metal Industries	ALTx	-0.02*	-0.10*	-0.11*	-0.05*
		ALTm	0.05*	-0.17*	-0.22	-0.37
38	Fabricated Metal prods., Machinery and Equipment	ALTx	0.35	0.24	0.11*	0.21
		ALTm	-0.47	-0.45	-0.38	-0.44
39	Other Manufacturing Industries	ALTx	0.14*	0.21	0.10*	0.28
		ALTm	-0.30	-0.28	-0.18	-0.27

All coefficients were statistically significant except for those denoted with * .

4.4.2: Country Specific Border Effects:

This section identifies country-specific border effects for the eight largest sectors using equation (3) by replacing OWN and oPCI with specific country dummies. Unrestricted SUR Regressions were run for each year 1970 to 1985 using Helliwell's internal distances. Pooled data with industry fixed effects gave similar results so are not reported.

To save space I report only the home bias in 1985 for each of the eight sectors. The other coefficients (GDP, POP, DIST, etc) were very similar to those presented above so are not reported. **TABLE 7** gives the border coefficients for each country for ISIC3 and sectors ISIC31-38. OECD average border effects, taken from **TABLE 6a**, are also listed for reference. Countries are ranked in descending order of their border effect at the aggregate level. As expected from the sectoral analysis, border coefficients for ISIC31 are very high in all countries while very low in ISIC37 in each country except Yugoslavia.

One unexpected result was the relative openness of ISIC32 (Textiles, Wearing Apparel and Leather) in the Scandinavian countries. For 1985, Denmark, Finland, Norway, and Sweden each had a border effect that was not significantly different from zero. Also surprising were the low effects for Australia, Portugal, and New Zealand in ISIC34 (Paper Products and Publishing). On the other hand, Canada was surprisingly inward orientated in ISIC34.

TABLE 4.7: SECTOR SPECIFIC BORDER EFFECTS (1985)

	ISIC3	ISIC31	ISIC32	ISIC33	ISIC34	ISIC35	ISIC36	ISIC37	ISIC38
OECD	**9.8**	**218**	**7.0**	**11.0**	**8.8**	**8.5**	**18.6**	**2.7**	**5.0**
BEL	0.1*	46	0.2*	2.3*	1.0*	0.0*	6.0*	0.0*	0.0*
NET	1.9*	102	0.0*	1.4*	2.9*	0.6*	5.5*	0.0*	0.0*
GER	2.8*	80	2.3*	2.8*	2.3*	1.2*	3.7*	0.6*	0.8*
FRA	3.7*	120	3.8*	1.5*	3.2*	1.9*	3.2*	0.7*	0.9*
UKG	4.9*	157	2.8*	2.3*	6.0*	2.5*	5.6*	1.4*	1.2*
USA	6.5	165	8.3*	6.8*	13.8	5.4*	4.1*	1.5*	1.7*
ITA	7.2	129	6.9*	4.6*	5.5*	6.0*	11.2	3.2*	2.2*
IRE	10.0	391	9.3*	10.3*	7.0*	0.0*	52.6	0.3*	0.0*
JPN	10.7	206	9.7*	9.5*	10.0*	8.6	10.0	2.5*	4.0*
AUT	11.8	226	6.6*	7.8*	4.0*	5.1*	26.9	2.6*	5.3*
DEN	12.3	304	3.6*	6.0*	9.9*	3.5*	31.1	0.8*	3.8*
NOR	12.6	210	2.8*	15.2	7.3*	7.7	23.0	0.9*	4.6*
SPN	13.2	273	13.2	14.8	11.2*	8.4	21.9	2.8*	4.2*
SWE	13.8	204	2.2*	16.0	11.8	8.9	17.7	3.0*	5.4*
CAN	18.3	334	18.1	26.6	21.3	14.4	24.7	8.0*	4.5*
AUS	20.5	233	15.8	27.2	12.4*	13.0	32.6	10.4*	11.8
TUR	22.0	286	14.0	17.3	21.9	41.2	20.6	3.2*	7.2*
FIN	24.1	333	7.3*	18.5	19.9	17.0	39.2	6.4*	6.9*
POR	28.2	311	17.5	44.4	11.0*	32.3	54.0	3.8*	11.0
NZL	34.1	210	17.5	80.5	9.4*	21.9	53.0	4.3*	33.8
GRC	45.1	477	49.3	53.2	16.1	49.0	82.1	7.8*	19.7
YUG	176	1425	124	183	121	177	124	35.5	111

Country –specific Border Effect for 1985 calculated from SUR regressions using Helliwell's measure of Internal Distance. OECD Border Effects are taken from Table 6a. Countries are ranked from lowest to highest by ISIC3. * denotes estimates that are not significantly different from zero.

4.5 ANALYSIS of COUNTRY and SECTORAL BORDER EFFECTS

Results from sections 3 and 4 show a high variation in both sector-specific border effects and country-specific effects. The question now posed is whether the differences we observe across countries can be explained by differences in their individual production patterns. For instance, is Germany so open because it focuses production on internationally traded goods (say ISIC38) while New Zealand is closed due to reliance on non-traded goods (ISIC31)? On the other hand, are border effects a result of national institutions and pan-sectoral factors that promote greater reliance on trade?

Which effect is creating borders may be important. If national biases are shaped by a nation's production patterns, which are in turn based on special geographic or national characteristics, then there may be little a country can do to lower those borders. For example, New Zealand is relatively closed compared to the OECD average. It may be because it is so isolated from most of the developed world that it must be self reliant in manufactured food-stuffs. Section 4 showed countries exported relatively little of their own production. Therefore, New Zealand will continue to be relatively closed to trade and there is little the government can do about this. Nor would they necessarily want to do anything since the home bias may balance the benefits and costs of external versus internal trade (Helliwell, 2000). In a similar vein, does Canada's reliance on resource based manufacturing doom it to be forever at the periphery of trading nations?

If, on the other hand, border effects are a function of constructed national institutions, then there might be room for policy initiatives. For example, assistance to industries attempting to start up foreign distribution networks may lower non-formal barriers to trade and so promote trade. Similarly, it may be critically important to reduce even small formal barriers to trade. The federal government's "Team Canada" approach to promoting greater trade with non-traditional partners might be one such tactic.

In this section, I try to assess whether national production patterns drive the pattern of country-specific border effects. First, we see that countries are relatively specialized in production and markedly different. **TABLE 4.8** gives the shares of ISIC3 production in each country for each two-digit sector in 1985. Australia, for example, has 21.5% of its manufacturing production in ISIC31 (FOOD) and 26.6% in ISIC38 (MACHINERY). The bolded entry in each column show the country with the highest degree of its production in that sector. Germany, for example, has 42% of its production in ISIC38. This is the highest of the OECD countries. It has only 12% in ISIC31. Much lower than the 42% that Ireland has.

TABLE 4.8: SHARES OF PRODUCTION IN MANUFACTURING 1985

		ISIC31	ISIC32	ISIC33	ISIC34	ISIC35	ISIC36	ISIC37	ISIC38	ISIC39
	Border Effect	**218**	**7.0**	**11.0**	**8.8**	**8.5**	**18.6**	**2.7**	**5.0**	**11.4**
AUS	**20.5**	0.215	0.065	0.050	0.078	0.140	0.047	0.132	0.266	0.007
AUT	**11.8**	0.189	0.079	0.053	0.072	0.156	0.054	0.085	0.306	0.006
BEL	**0.1**	0.154	0.086	0.042	0.042	0.228	0.040	**0.136**	0.272	0.001
CAN	**18.3**	0.167	0.051	0.059	0.098	0.201	0.025	0.074	0.309	**0.014**
DEN	**12.3**	0.365	0.050	0.042	0.087	0.127	0.036	0.016	0.264	0.013
FIN	**24.1**	0.180	0.046	0.065	**0.231**	0.182	0.031	0.068	0.192	0.005
FRA	**3.7**	0.189	0.067	0.021	0.059	0.244	0.026	0.067	0.317	0.010
GER	**2.8**	0.123	0.056	0.038	0.047	0.197	0.031	0.075	**0.424**	0.009
GRC	**45.1**	0.240	0.181	0.046	0.043	0.206	**0.064**	0.064	0.152	0.005
IRE	**10.0**	**0.417**	0.082	0.032	0.067	0.113	0.061	0.009	0.209	0.010
ITA	**7.2**	0.131	0.111	0.026	0.040	0.231	0.048	0.098	0.305	0.012
JPN	**10.7**	0.124	0.047	0.027	0.057	0.196	0.036	0.083	0.416	0.013
NET	**1.9**	0.266	0.029	0.021	0.073	**0.353**	0.025	0.039	0.190	0.003
NOR	**12.6**	0.222	0.021	0.066	0.117	0.206	0.028	0.093	0.241	0.004
NZL	**34.1**	0.300	0.091	**0.112**	0.077	0.094	0.034	0.043	0.239	0.011
POR	**28.2**	0.191	**0.184**	0.082	0.067	0.199	0.060	0.044	0.172	0.002
SPN	**13.2**	0.211	0.088	0.047	0.069	0.193	0.058	0.085	0.242	0.007
SWE	**13.8**	0.131	0.020	0.072	0.148	0.174	0.023	0.070	0.355	0.006
TUR	**22.0**	0.202	0.132	0.027	0.065	0.282	0.049	0.087	0.155	0.002
UKG	**4.9**	0.195	0.055	0.027	0.080	0.214	0.030	0.082	0.309	0.010
USA	**6.5**	0.140	0.050	0.027	0.085	0.253	0.023	0.059	0.354	0.010
YUG	**176**	0.163	0.128	0.053	0.068	0.160	0.037	0.121	0.266	0.004
AVG	9.8	0.211	0.091	0.050	0.080	0.166	0.040	0.082	0.273	0.007

Shares are calculated as a fraction of total ISIC3 production in each country.

Border Effect refers to the sector specific border effect for 1985 taken from Table 6a.

Country–specific Border Effect for 1985 taken from Table 8.

The first row in **TABLE 4.8** shows the estimated border effects for each sector in 1985 taken from **TABLE 4.6a**. ISIC38 has a much lower border effect than ISIC31. Given the dissimilarity in production between, say, Germany and Ireland, and the difference in sectoral borders, we would expect Germany to have a lower border effect than Ireland. In fact it does. Each country's border effect is given in column 2. The question is whether the different production patterns, in conjunction with differences in sectoral propensities to trade, explain a significant proportion of the difference in borders across countries. It turns out that they cannot explain much. The following four sections explore different aspects of this. The results presented below may be sensitive to mis-measured internal distances. However, the consistency of the results across the different analyses suggests that the underlying claim will survive under more robust estimates of internal distances.

4.5.1 Constructed Country-Specific Border Effects

One way to see if production patterns are a major factor in explaining country-specific border effects is to artificially construct an aggregate border effect from sectoral borders in **TABLE 4.6a** using sectoral concentrations as weights. The hypothesis is that this constructed border effect should closely approximate estimated borders in each country if production patterns were the driving force behind national border effects.

To do this, I calculated a weighted border effect for each country in each year. It is the sum of (logged) sectoral border effects taken from **TABLE 4.6a** using the country's sectoral shares from **TABLE 4.8** as weights. I did this for each year using weights and border effects for that year. Results for 1985 are reported in **TABLE 4.9**. Columns two and three give each country's SUR estimates and their ranks. Columns four and five give the constructed border effects and ranks for each country. I ranked and sorted countries by their estimated SUR home bias for ISIC3 in 1985. How well does the constructed measure do? For 1985, the correlation between (the antilog of) the estimated home bias and the constructed home bias is 0.176 with the Spearman Rank correlation coefficient higher at 0.293[15]. Notice that all countries except New Zealand change their rankings. The Netherlands falls to a rank of 19 from 2 because of its heavy reliance on ISIC31 (FOOD) and ISIC35 (CHEMICALS) production. Japan rises to 2 from 9 because of its concentration in

[15] This is significant at the 5% level: we would reject the null hypothesis that the rankings are not positively correlated.

ISIC38 (MACHINERY, TRANSPORT, etc). Yugoslavia, ranked last in measured home bias, ranks 7th in the weighted average.

Using the entire sixteen-year sample, I can construct a psuedo-r^2 between the estimated border effects and the "predicted" border effects. This yields a value of 0.1021. That is, about 10% of the variation in the estimated border effect can be explained by variations in the weighted-average sectoral border effect. Alternately, an OLS regression of estimated border effects (in logs) and the weighted border effect (also in logs) yields an r^2 of 0.1296. In either case, these results were significantly above zero but not spectacularly high. I conclude that the sectoral composition of a country's production has some impact on its border effect, but not a lot.

TABLE 4.9: CONSTRUCTED BORDER EFFECTS (1985)

	BEsur[1]	rank	BE w[2]	rank	BE pci[3]	rank
BEL	0.1	1	11	6	7.0	8
NET	1.9	2	18	19	7.8	13
GER	2.8	3	9	1	6.6	6
FRA	3.7	4	12	9	6.5	5
UKG	4.9	5	13	11	7.7	12
USA	7.0	6	11	5	4.7	1
ITA	7.2	7	10	3	7.9	15
IRE	10.0	8	30	22	13.6	18
JPN	10.7	9	10	2	7.6	11
AUS	11.8	10	13	13	7.5	10
DEN	12.3	11	24	21	6.1	4
NOR	12.6	12	14	17	5.1	2
SPN	13	13	14	15	12.3	17
SWE	13.8	14	10	4	6.9	7
CAN	18.3	15	12	8	5.4	3
AUT	20.5	16	13	10	7.8	14
TUR	22.0	17	14	14	38.4	21
FIN	24.1	18	13	12	7.3	9
POR	28.2	19	14	16	23.4	20
NZL	34.1	20	20	20	9.5	16
GRC	45.1	21	16	18	18.0	19
YUG	176	22	11	7	71.8	22

1 BEsur is taken from Table 7.

2 $BEw_j = \exp(\Sigma^s [w^s_j \, BE_{OECD}{}^s])$ where w^s_j is country j's share of production in sector s, OECD refers to the average country effect

3 $BEpci_j = \exp([BE_{OECD} + \ln (PCI_j/PCIm) \, oPCI_{OECD}]$ where OECD refers to the average country effect

As a point of comparison, I also constructed a border effect using each country's deviation of GDP per capita from the OECD mean. This was calculated for each year and country as $BE_j = \exp([BE_{OECD} + \ln (PCI_j/PCIm) \sigma PCI_{OECD}]$ where OECD refers to the average country effect (taken from **TABLE 4.4a**). The results for 1985 are in columns six and seven of **TABLE 4.9**. Notice now that the USA has the lowest measure since it is the richest country in the group. Yugoslavia has the highest border effect since it is poorest. How does this measure do? It does pretty well. Constructing a psuedo-r^2 yields a value of 0.6162. Regressing the SUR border effects on the constructed border effect yields an r^2 of 0.6205. In either case, GDP per capita appears to be up to six times more important in explaining measured border effects than does country's sectoral production mix.

4.5.2 Correlations Across Sectoral Border Effects

Here I look at correlations of border effects across sectors within countries. If sectoral effects were the only factor driving aggregate border effects, then we would not expect country-specific sectoral border effects to show similar patterns in each industry. That is, a country might be very open in some sectors but not in others depending upon particular circumstances in that country. The correlation between border effects across sectors, within a country, would be low. It turns out that they are high.

Using border coefficients and rankings for all sixteen years, I am able to generate correlation coefficients between sectors. These are reported in **TABLES 4.10a** and **4.10b**. For example, the correlation between country-specific border effects in ISIC31 and ISIC32 is 0.560. We can see that the correlations are positive and quite high. The lowest correlation is between ISIC36 and ISIC37 at 0.490 The highest is between ISIC37 and ISIC38 at 0.990. **TABLE 4.10b** shows Spearman's Rank Correlation Coefficients for country rankings across sectors for 1985. Correlations tend to be higher with the lowest at 0.532 and the highest at 0.960.

The data clearly shows that countries that have a relatively low home bias in one sector have a relatively low home bias in all sectors. Some of this high correlation is undoubtedly caused by systematic mismeasurement of internal distances or entrépot trade. It's hard to assess how much.

TABLE 4.10a: CORRELATION BETWEEN ESTIMATED SECTORAL BORDER EFFECTS: 1985

	ISIC3	ISIC31	ISIC32	ISIC33	ISIC34	ISIC35	ISIC36	ISIC37	ISIC38
ISIC3	1.000	0.917	0.704	0.966	0.875	0.971	0.919	0.688	0.742
ISIC31		1.000	0.560	0.826	0.942	0.878	0.804	0.539	0.570
ISIC32			1.000	0.653	0.626	0.757	0.502	0.992	0.986
ISIC33				1.000	0.773	0.921	0.933	0.631	0.707
ISIC34					1.000	0.879	0.657	0.607	0.620
ISIC35						1.000	0.855	0.735	0.776
ISIC36							1.000	0.490	0.568
ISIC37								1.000	0.990
ISIC38									1.000

Correlation is for $(\ln(BEj)^S, \ln(Bej)^T)$ for sectors S and T for all countries in 1985.

TABLE 4.10b: SPEARMAN'S RANK CORRELATION COEFFICIENT BETWEEN SECTORAL BORDER RANKS: 1985

	ISIC3	ISIC31	ISIC32	ISIC33	ISIC34	ISIC35	ISIC36	ISIC37	ISIC38
ISIC3	1.000	0.806	0.784	0.960	0.797	0.937	0.848	0.875	0.958
ISIC31		1.000	0.755	0.781	0.749	0.653	0.866	0.656	0.659
ISIC32			1.000	0.810	0.722	0.784	0.688	0.805	0.717
ISIC33				1.000	0.772	0.898	0.843	0.849	0.914
ISIC34					1.000	0.838	0.532	0.793	0.722
ISIC35						1.000	0.652	0.922	0.940
ISIC36							1.000	0.664	0.758
ISIC37								1.000	0.879
ISIC38									1.000

4.5.3 Tariff and Non-Tariff Barriers to Trade

A third test of whether sectoral composition of production matters is to see if tariff and non-tariff barriers are significant factors in explaining border effects at the aggregate or sectoral levels. If formal barriers were the primary factor, then accounting for these barriers should eliminate the home bias. If, however, formal barriers do not explain much of the border effect, then we need to identify non-formal barriers (institutional factors) as the primary cause.

We can test whether formal barriers explain the home bias. Harrigan (1993) uses data on tariff and non-tariff barriers from 1983 to identify whether, and to what extent, they affect trade in the OECD. His data set is conformable to the data I use and so can be used to identify their effects on measured home biases.

Harrigan analyzes three kinds of non-tariff barriers based on coverage ratios for the thirty three-digit ISIC categories: price barriers, quantity barriers, and threat barriers:[16] the bigger the number, the more widespread the coverage, and presumably the bigger the barriers to trade. These coverage ratios are reported in a partial bilateral matrix involving thirteen countries importing from sixteen countries. Harrigan also reports average tariff rates and average NTB-coverage ratios. This gave a total of 120 observations. We can add 13 observations of internal trade by assuming internal trade is barrier free.

I used OLS regression to identify the border effect without measured trade barriers. The dummy variables for language, adjacency, ocean access were not significant so were dropped. ALTx and ALTm were also dropped for the same reason. The EU dummies were dropped since they were used as a proxy for low trade barriers. Since the barriers were measured as coverage ratios, I took Harrigan's suggestion and converted them by taking the log of (1 + ntb) for each of the barrier types.

TABLE 4.11 shows the regression results for aggregate ISIC3 trade. The set of countries gave an average border effect of 4.29. This is not surprising since the countries were already identified as having low borders.

Bringing non-tariff or tariff barriers into the regressions, either one by one or together, did not lower the border effect. In fact it typically raised the measured border effect by a small, but not a significant, amount. This is more or less consistent with Head and Mayer's conclusion that there is little evidence to support a claim that border effects are positively related to NTBs in the EC (p 23).

The trade barriers had the expected effect on trade except for price barriers. Only average tariffs seemed to be of any significance. A rise of one percent in average tariffs tended to reduce trade by almost two percent. An increase of one percent in average NTB coverage rates decreased trade by about 0.6 percent. Threat NTBs seemed to be more

[16] This data is also available on the NBER World Trade Data Disc 2. See Harrigan (1993) for a more thorough discussion on the construction of the data.

important than Quantity NTBs though less precisely measured. The unexpected result was that Price NTBs were positively correlated with trade. A rise of one percent in Price NTBs tended to raise trade by about 1.3 to 1.8 percent. This positive relation suggests that political economy motives are dominating the trade restricting effects.

As shown in TABLE 11 border effects were largely independent of formal trade barriers in whatever form they took. The issue here seems to be that the formal barriers to trade were positively correlated to distance. The nearer the trading country, the lower the legislated barriers. For example, the lowest barriers were among the EU countries. Most of these are neighbors. This meant that the elasticity of trade with respect to distance fell once barriers were introduced. It seems that the distance variable in the previous regressions was absorbing some of the effects of formal barriers. However, we still see countries focusing a lot of production for the home market even with neighboring countries offering low formal barriers.

To test the robustness of these results I used the pooled sample for 1983 and the sector-specific tariff and non-tariff barriers provided at the three-digit level by Harrigan. Measured border effects were, again, uniformly higher depending on the NTB used although seldom significantly so. I also ran regressions for individual three-digit sectors and got similarly small changes in border effects.

The conclusion appears to be that formal trade barriers are sufficiently low that they have only a small impact on trade. They seem incapable of explaining the magnitude of the home bias in trade.

TABLE 4.11: NON-TARIFF AND TARIF BARRIERS: 1983

	1	2	3	4	5	6	7	8	9
R^2 ADJUSTED	0.8780	0.8778	0.8794	0.8770	0.8784	0.8800	0.8792	0.8810	0.8797
lnGDPx	-0.0882 -0.15	0.0072 0.01	-0.1259 -0.22	-0.0852 -0.15	-0.3228 -0.53	-0.0311 -0.05	-0.3481 -0.57	-0.2848 -0.47	0.0526 0.09
lnGDPm	1.2983 2.30	1.1946 2.07	1.1890 2.10	1.2966 2.28	1.5188 2.56	1.2147 2.16	1.4475 2.38	1.3567 2.23	1.1243 1.96
lnPOPx	0.9380 1.61	0.8236 1.38	0.9598 1.66	0.9346 1.59	1.2073 1.94	0.8682 1.50	1.2185 1.94	1.1417 1.83	0.7678 1.30
lnPOPm	-0.5149 -0.91	-0.4186 -0.72	-0.4149 -0.73	-0.5134 -0.90	-0.7297 -1.22	-0.4550 -0.81	-0.6689 -1.10	-0.6009 -0.99	0.7678 -0.64
lnDIST	-0.9149 -17.06	-0.8712 -11.99	-0.8547 -13.01	-0.9142 -16.30	-0.9492 -15.60	-0.8826 -15.71	-0.8861 -11.48	-0.8547 -10.86	-0.8445 -11.45
AVERAGE NTB ln(1 + aNTB)		-0.6295 -0.89							-0.5617 -0.80
QUANTITY NTB ln(1 + qNTB)			-1.0996 -1.57				-1.0001 -1.37	-0.9946 -1.37	
THREAT NTB ln(1 + tNTB)				-0.0600 -0.04			-1.8344 -1.05	-1.6747 -0.96	
PRICE NTB ln(1 + pNTB)					1.3342 1.19		1.8033 1.27	1.7123 1.21	
AVG TARIFF ln(1 + tarNTB)						-1.9212 -1.77		-1.8537 -1.71	-1.8724 -1.72
OWN	1.4552 5.40	1.4803 5.46	1.5107 5.59	1.4554 5.38	1.4441 5.37	1.4803 5.54	1.4940 5.51	1.5183 5.64	1.5020 5.58
CONSTANT	1.5810 0.79	2.2690 1.05	2.9543 1.35	1.6397 0.67	0.0424 0.02	3.7600 1.61	2.5448 0.90	4.5890 1.51	4.3186 1.76
BORDER	**4.29**	**4.39**	**4.53**	**4.29**	**4.24**	**4.39**	**4.45**	**4.56**	**4.49**

t-statistics are reported below each coefficient. Border is calculated as exp(OWN).

4.5.4 Specialization and Border Effects

Suppose a country concentrates production in one sector, say machinery, but is diversified in consumption. We expect its border coefficient in that sector to be low. The reason is that the country would need to export much of its production to purchase imports in other sectors. Therefore, its net internal trade in that sector would be low relative to its external trade. Border effects in other sectors would be correspondingly higher. This implies that there should be a negative correlation between a country's sectoral production shares and its (logged) sectoral border effects. We can check for this. The first row in **TABLE 12** shows this correlation for 1970 to 1985. For instance, the correlation between countries' share of production in ISIC31 and their border effects in ISIC31 is 0.154. The larger the share of production held in ISIC31, the larger the average border effect. This is opposite of what we would expect. In fact, the correlations are negative for only two of the eight sectors. This indicates that countries tended to have a larger home bias in those sectors that they were more heavily concentrated in. We get the converse only in sectors ISIC35 and 38. Here, countries with a greater share of their production in that sector seemed to target a higher proportion of production for exports. It's not clear why these two sectors would differ from the others although it might be related to access to markets. Recall that these were sectors with ALTx strongly positive and ALTm negative (as was ISIC36). This suggests that, for these sectors, proximity to markets might lead to concentration in both production and exports. This does not appear a factor in the other sectors.

TABLE 4.12: Correlation between Production Shares and Country Border Effect 1970-85

	ISIC3	Isic31	Isic32	isic33	Isic34	isic35	isic36	Isic37	Isic38
Share of ISIC3[1]		0.154	0.572	0.370	0.076	-0.072	0.340	0.251	-0.126
OECD Share[2]	-0.303	-0.311	-0.041	-0.192	-0.051	-0.112	-0.532	-0.112	-0.139
Relative OECD Share[3]	0.231	0.242	0.109	0.241	0.160	0.129	0.278	0.079	0.157

1 Correlation is for $(SHj^S, \ln(BEj^S))$ where SHj^S is industry s's share of country j's total ISIC3 production. BEj^S is country j's border effect in sector S.
2 Correlation is for $(SHj^S, \ln(BEj^S))$ where SHj^S is country j's share total OECD ISIC3 production in industry S.
3 Correlation is for $(SHj^S, \ln(BEj^S))$ where SHj^S is (country j's share total OECD ISIC3 production in industry S)/(country j's share total OECD GDP)

A second relationship can also be derived. Suppose now that OECD production in a particular sector is concentrated in a few countries. Those countries should then become a common export source to all the other nations. These exporting countries would have a high export to internal-trade ratio and so have low border effects in that sector. Hence, countries with large shares of OECD production in a particular sector will tend to export relatively more of that sector and so have a lower border effect. Row two in **TABLE 4.12** is the correlation between the share of OECD production in that sector that resides in a particular country and that country's home bias. As expected this is a negative value: countries with a larger share of OECD production tended to have lower border effects.

However, this may be driven purely by country size since the four biggest countries are ranked in the top eight countries in terms of lowest home biases. The smaller countries tended to have bigger border effects. Row three shows the same correlation between home bias and OECD production shares where those shares are scaled by the country's share of OECD GDP. For instance, in 1985, the Netherlands produced 2.3% of the OECD's ISIC31 production but had 1.6% of its GDP. They would be considered relatively concentrated in ISIC31. Germany, on the other hand, produced 5.4% of ISIC31 but had 7.8% of OECD GDP so would have a low, relative, concentration in ISIC31. Those countries with a relatively large share of production should export relatively more production and so have lower borders. Row three of **TABLE 4.12**, however, shows that this correlation is positive in all sectors: countries with a relatively large concentration in a sector also have a larger border effect in that sector. This effect was smallest in ISIC35 and ISIC38. This is a similar pattern to that for concentration in production.

There was one relationship between concentration of production and border effects that accorded with intuition. The more OECD production was concentrated geographically, the lower the border effect appeared to be. To find this I constructed two measures of geographic concentration. The first was a Herfindahl index that is the sum of squared OECD production shares held in a country in a particular sector. The second is a dispersion index that is the squared sum of differences between a country's OECD production share in a sector and its GDP share. The larger either of these two measures, the greater the degree of geographic concentration. The Herfindahl index, however, suffers in that it tends to remain constant over time. The dispersion index rose in each sector over the period. **TABLE 4.13** shows both measures and the correlation with each sectoral border effect for the sixteen years. The expectation is that the higher the geographic concentration, the more the good is traded, and the lower the border effect. This seems to hold. In only eight of 28 industries was this correlation the wrong sign using the Herfindahl index and in nine using the dispersion index. It was negative for all the subaggregates using the dispersion index and in six using the Herfindahl index. It was negative for both using aggregate data.

TABLE 4.13: GEOGRAPHIC CONCENTRATION and INDUSTRY BORDER EFFECTS: 1985

ISIC	DESC	BE[1]	HiGEO[2]	COR[3]	GEO[4]	COR[5]
3	**MANUFACTURING**	9.8	0.243	-0.257	0.007	-0.809
31	**FOOD, BEVERAGES, AND TOBACCO**	217	0.208	-0.283	0.002	0.214
311	food manufacturing	185	0.206	-0.004	0.002	0.175
312	other food manufacturing	159	0.248	-0.195	0.014	0.326
313	beverage industries	314	0.204	-0.341	0.008	0.183
314	tobacco manufactures	475	0.205	-0.020	0.026	0.122
32	**TEXTILE, WEARING APPAREL AND**	7.0	0.197	-0.028	0.002	-0.074
321	manufacture of textiles	20.5	0.199	-0.229	0.004	0.272
322	manufacture of wearing apparel (except	1.3	0.237	0.275	0.003	0.310
323	manufacture of leather products (except	3.7	0.137	-0.044	0.034	-0.559
324	manufacture of footwear (except rubber or	4.3	0.124	0.680	0.037	-0.658
33	**MANUFACTURE WOOD AND WOOD**	11.0	0.188	0.218	0.006	-0.183
331	manufacture wood, wood and cork prod.	8.7	0.208	0.005	0.009	0.090
332	manufacture furniture, fixtures (except	19.5	0.164	0.551	0.008	-0.565
34	**MANUFACTURE PAPER**	8.8	0.283	-0.383	0.015	-0.591
341	manufacture of paper and paper products	6.4	0.289	-0.516	0.018	-0.724
342	printing, publishing, and allied industries	72.9	0.280	-0.080	0.014	-0.155
35	**MANUFACTURE OF CHEMICALS AND**	8.5	0.279	-0.442	0.011	-0.580
351	manufacture of industrial chemicals	3.6	0.235	-0.555	0.004	0.445
352	manufacture of other chemical products	24.7	0.257	0.181	0.006	-0.402
353	petroleum refineries	20.2	0.336	-0.237	0.029	-0.078
354	misc. products of petroleum and coal	8.1	0.253	-0.291	0.024	-0.092
355	rubber products	4.8	0.234	0.182	0.005	-0.370
356	plastic products n.e.c.	10.5	0.275	-0.579	0.026	-0.704
36	**MANUFACTURE NON-METALLIC MINERALS**	18.6	0.187	0.069	0.016	-0.719
361	pottery, china, and earthware	20.6	0.160	-0.713	0.103	-0.817
362	glass and glass products	11.3	0.229	0.495	0.004	-0.290
369	other non-metallic mineral products	35.1	0.189	-0.083	0.023	-0.474
37	**BASIC METAL INDUSTRIES**	2.7	0.201	0.006	0.012	-0.655
371	iron and steel basic industries	1.6	0.188	-0.148	0.026	-0.810
372	non-ferrous metal basic industries	3.2	0.256	-0.148	0.009	-0.568
38	**FABRICATED METAL PRODS., MACHINERY**	5.0	0.263	-0.025	0.014	-0.451
380	metal scrap from manufacture of fabricated		0.626		0.587	
381	fabricated metal products	9.9	0.265	-0.119	0.013	-0.427
382	manufacture of machinery (except electrical)	2.3	0.260	-0.317	0.009	-0.629
383	electrical machinery, apparatus, appliances	2.7	0.268	-0.212	0.029	-0.540
384	transport equipment	1.8	0.257	0.136	0.011	-0.007
385	prof., scientific, measuring, and control	1.6	0.335	-0.455	0.037	-0.847
39	**OTHER MANUFACTURING INDUSTRIES**	11.4	0.265	0.129	0.018	-0.690

1 BE is industry specific border effect in 1985

2 HiGEO is a Herfindahl Index of Geographic Concentration for 1985 calculated as $[\Sigma^j (s_j)^2]$ where s_j is country j's share of total OECD production in that sector.

3 This is the correlation between ln(BE) and HiGEO for 1970-85

4 GEO is a dispersion index of Geographic Concentration for 1985 calculated as $[\Sigma^j (s_j)^2]$ where s_j is (country j's share of total OECD production – GDP share of country j of total OECD GDP).

5 This is the correlation between ln(BE) and GEO for 1970-85

4.6 CONCLUDING REMARKS:

The purpose of this paper was to first identify the existence of border effects in a data set not previously used in this fashion. I found that border effects for an average OECD country from 1970 to 1985 were consistent with previous estimates. In 1970, an average OECD country traded about 30 times as much with itself than was expected once geographic location, economic size, and transaction costs were accounted for. By 1985, this had fallen to 10. Country-specific border effects also confirmed existing estimates with many EU countries very open to trade. Despite the fall in average border effects, many countries remained relatively closed even by 1985. I also confirmed that per capita income was an important factor in determining a country's home bias.

I was able to identify border effects for sub-aggregates and showed that these too followed the trends for the aggregate. A number of sectors showed that production was for OECD consumption while others showed that production was focused primarily on domestic markets.

The second purpose of the paper was to use this new information on sectoral borders to assess whether country-specific border effects could be generated by purely sectoral factors. I showed that this was unlikely. Though of some importance, it could not explain much of the variation in border effects across countries. The primary factor in determining the degree of home bias in trade appears to be the level of economic development within a country. I base this on four pieces of information. First, I constructed country-specific border coefficients, using sectoral production shares as weights. I also constructed them using countries' deviation from mean per capita income. Results showed that national production patterns had small explanatory power while deviations in GDP per capita could explain up to two thirds of country variations. Second, there was strong correlation of border effects across sectors within countries. Third, inclusion of formal tariff and non-tariff barriers at the industry level did not alter measured border effects at all. It had no effect at the aggregate or subaggregate levels. Fourth, industrial concentration of production within a country or within the OECD did not have the expected correlation with country-specific home biases. It did seem to explain sectoral patterns.

I conclude that pan-sectoral factors, rather than industry specific factors, contribute the most important influence in determining the strength of border effects within a country.

Further, as countries become more developed, these national institutions become transformed and facilitate a more outward orientated trade posture. It is unclear though, whether all countries will experience the degree of integration of some of the European countries.

Of course, the analysis above did not explain why some sectors have such high border effects while others had small effects. One possible explanation, partially explored in the chapter, was that access to large export markets increases the density of trade for some sectors. This may provide a comparative advantage and so promote exports. It suggests that country-specific geographic location might matter a lot within particular industries. A second feature is that there was an increase in the geographic concentration of production in the OECD as industries rationalized operations. This was more evident in some sectors than others. This may partially explain the secular decline in border effects. However, more research is required to identify to what extent these factors contribute to increased trading densities.

CHAPTER 5: RECOMMENDATIONS FOR FUTURE RESEARCH

5.1: Environmental Regulation and Market Structure

There are two sensible extensions of the first essay that appear fruitful. First, the model was constructed with the number of firms in the industry predetermined. The regulator, given the market structure, had to find the level, or kind, of regulation to impose. This is a useful assumption as it simplifies the problem considerably. It highlighted how the form of regulation interacted with the degree of competition to condition the regulator's choices. The results showed that each form of regulation created different pressures on profits. Design Standards tended to lower profits; Emission Standards could raise or lower profits; and Output Standards tended to raise profits. These were all in relation to unregulated firms.

If, however, the number of firms were endogenous, then the form of regulation would impinge on the number of firms that could profitably exist in the industry. The assumption would be that firms enter until there are zero profits. Costs would include a fixed component so as to limit entry to a finite number. Social costs would be partially determined by the number of in the industry and industry output.

For an environmental regulator, the problem is to attain the desired target at least social cost. The number of firms left in the industry after regulation would matter. This is an interesting problem. In Cournot competition, the number of firms that exist under free-entry often exceeds the social optimum. There are simply too many firms. This excess competition due to excessive entry is another distortion that would need to be addressed. The regulator would want to reduce the number of firms without also reducing industry output too much. Design Standards do this since profits fall under regulation. It would allow the remaining firms to expand production. Emission Standards might induce entry while simultaneously reducing industry output. This worsens both distortions. Output constraints would be even worse. Design Standards therefore might perform even better than indicated in Chapter 2. This would tend to strengthen the role for traditional Command and Control over incentive-based regulation.

Second, the model assumes that all firms are identical. The idea was to identify how the different regulations worked in the simplest model possible. The focus was how regulations modulated the degree of competition between firms. Homogeneity is clearly a strong assumption. Firms can differ both in size or in how easily they can accommodate regulation. However, the symmetric application of regulations to non-symmetric firms would affect each differently and so alter the competitive pressure between firms. There are two dimensions in which one could pursue this. First, suppose firms have identical cost structures but differ in that one firm has an advantage over the other. For instance, consider the Stackleberg leader-follower problem. The leader has a strategic advantage over the follower in that it can commit to a higher level of output. The follower is forced to reduce output in response. Now, suppose we impose a Design Standard that applied equally to each firm. The fixed cost nature of the Design Standard can create an opportunity for the leader to block entry of the follower. This entry deterrence would not be present under Emission Standards. Hence, with asymmetric firms, Design Standards may be less conducive to competition than I had found in Chapter 2.

A different argument can be made that would show that Output constraints remove some, or all, of the advantage that the leader enjoys. Similarly for Concentration and Emission Standards. The advantage of the leader would be eroded by regulation, as it must adjust more than the follower.

Each firm will have a different set of preferences over instruments so can be expected to lobby for different forms of regulation.

Hence the form of regulation again interacts with competitive forces in different, and interesting, ways. It is important to identify these different forces since many industries are dominated by a small number of large firms.

The second dimension is that firms can differ in their ability to adapt to regulations. They have different abatement technologies or better access to cleaner inputs and recyclables. The main argument for incentive-based regulations is that it permits firms to adopt different levels of abatement and so allows the regulator to achieve an efficient distribution of emissions across firms. This can yield substantial savings. Chapter 2 does not contradict that finding as Command and Control regulations are almost always defined as a firm-specific constraint. They do not, typically, allow firms different activities. The comparison between Command and Control and incentive-based regulation becomes more favourable to incentive-based instruments.

However, Command and Control instruments are not equivalent to one another. The rankings that were established in Chapter 2 may not hold when firms differ. The issue is how a common standard, applied to dissimilar firms, affects each firm individually. For instance, suppose firms have identical production costs but different abatement technologies. A common Emission or Concentration Standard will hurt high marginal abatement cost firms more than low marginal abatement cost firms. This can cause the industry to diffuse where the industry goes from having identically sized firms to one where firms differ in size. Common Design Standards and Output Constraints on the other hand would maintain homogeneity. It is unclear what the welfare effects would be since it would depend on the number of firms in the industry. Also, the preferences of firms would likely differ.

5.2: Environmental Design and the Race To The Bottom

As with Chapter 1, I can see two sensible extensions of the model used in Chapter 2. Both deal with how the choice of instruments affects the level of environmental quality. First, Barrett (1994) showed that, as the number of firms in the domestic industry rose, the strategic effect fell. In fact, the regulator might impose supra-Pigouvian targets so as to diminish *domestic* competition for world markets. Barrett's argument was that the regulator could increase the total size of rents extracted from world markets by contracting local production. It sacrificed a small part of its *share* of total rents but raised the *volume* of rents more than enough to offset that loss. Both nations were better off while world consumers were worse off.

In the model I presented, Design Standards could not alter marginal costs so could not constrict domestic production. The optimal target would be a function of the number of domestic firms but would still be determined non-strategically. Design standards would continue to isolate a country from foreign regulations.

This weakening of the strategic effect applies only to Emission Standards and Charges. Extending Barrett's logic suggests that, as the number of domestic firms rise, we would expect a race to the bottom to be less likely. Also, the joint payoff would rise as each country curbs their firms.

We would want to identify two results. First is whether the range of parameters for which Design Standards dominates shrinks as the number of firms rise. It likely will. If it takes only a few firms to eliminate the race to the bottom, then a movement to incentive-based regulations would likely, as Esty claimed, reduce the tension between countries.

The second question would be whether it becomes more difficult to unilaterally adopt Emission Standards if the other country maintains its Design Standards. Recall that the country using Design Standards confers to its industry a strategic commitment to high output. This allows it to gain considerably if the other restricts its firms. This suggests that the range for which a Prisoner's dilemma emerges in Design Standards could expand. This would increase the need to coordinate instrument choice.

The second extension relates to the way countries apply import rules based on the environmental performance of importing companies. A common proposal is for countries to harmonize these import rules to facilitate trade. The standard treatment is to consider harmonization of levels rather than of modes. Countries differ in many dimensions so the presumption is against harmonization of levels. Bhagwati (1996) discusses the argument for and against such harmonization. There are, however, a number of ways countries can differ in *how* they treat imports. This presents a different sort of harmonization claim. One approach to harmonization is *equivalency*; foreign goods must be made under standards that are equivalent to, or exceed, domestic standards. In contrast, *mutual recognition* only requires that the foreign firms meet foreign standards. Foreign and domestic standard can differ. The question is how the different forms of import restrictions affect the level of the standard chosen.

One could model this by using a variant of the Reciprocal Dumping Model as presented in Brander (1995). There, two countries simultaneously produce and trade goods. Firms compete in both markets (reciprocal dumping). This creates cross-hauling. The degree to which this occurs is a function of the level of economic integration between the two countries. The level of barriers-to-trade and transportation costs measures this degree of integration. Now, suppose production generates local pollution only. Governments will allow imports based on either an Equivalency or Mutual Recognition basis. The question is how the two modes affect the incentive to control local pollution. This parallels the question asked in Chapter 3.

The model will tend to generate two totally different results based on the mode of harmonization. Mutual Recognition would tend to promote a race to the bottom.

Governments would ease their own standards to give domestic firms a cost advantage in both markets. The tradeoff is the additional pollution damage. This is essentially the same problem presented in Chapter 3 except production was for export only.

Equivalency, on the other hand, could work in the opposite way. It could encourage countries to raise domestic standards so as to exclude imports. Strategic interaction might induce a race to the top. The question here is whether the pressure to raise standards is sufficient to overcome the loss in consumer surplus from shutting out imports. One general question is how the degree of integration affects incentives to manipulate targets. This becomes more important as countries reduce formal barriers to trade and international transactions costs fall.

5.3: Border Effects in OECD Manufacturing Industries: 1970 to 1985

There are two kinds of research activities I envision coming out of the empirical component of Chapter 4. The first is to sharpen the results presented in the Chapter by expanding the data set and checking robustness. The second is to pursue interesting results identified but not the focus of the chapter.

To sharpen results in the Chapter I would want to extend the data set in three dimensions. First, it would be useful to extend the period covered up to 1995. This would provide more information about the current level of home biases as well as how macroeconomic factors such as recessions have affected the evolution of home biases.

The second is to broaden the number of countries in the sample to include more non-OECD countries. This could be accomplished for a particular year or set of years. It would expand the variance in per capita incomes and allow a stronger test that per capita income is the primary determinant of country-specific border effects.

The third is to include agricultural and mining sectors so that all merchandise trade is included. The data used was restricted to manufacturing data. Although manufactures make up about 80% of merchandise trade in the OECD, it is lower for countries like Canada, Australia, and Norway. This might be important. The relative rankings might change somewhat as more inclusive data is included. It would also provide a full coverage of border effects across all merchandise sectors.

These extensions are possible but give rise to two problems. First, trade data is reported in SITC categories so would need to be made conformable to ISIC categories. The data set I used was already transformed. Making new trade data conformable is difficult and tedious but can be done.

The second is that the value of production at the three and four digit ISIC level is reported for all countries by the United Nations only up to 1992. After this, data is restricted to the amount, rather than value of production. The OECD, on the other hand, reports production values past 1992 but only at the two-digit level. The UN also has this data but for non-OECD countries as well. This presents two problems. One, there is a break in the production series. It is unclear how critical this is. Two, is not possible to accomplish the same set of tasks as I performed in Chapter 4 as the three-digit data is unavailable.

Robustness also needs to be pursued as well. The most pressing aspect is to obtain more accurate estimates of internal distances. The size of the border effects is, roughly, proportional to the measure of internal distances. Doubling an internal distance will approximately double a country's border effect. Relative rankings of country-specific border effects are sensitive to the measure used. Hence a more accurate and systematic estimate of internal distances is required before we can take measures of country-specific border effects more seriously. These measures are important since border effects give a comprehensive assessment of a country's propensity to trade.

Propensity to trade has been an important determinant in many studies. For instance, researchers have used measures of openness to explain patterns and rates of growth or the willingness to create inflation. A typical measure of a country's *openness* to trade is to take the sum of a country's total exports and imports and divide by total GDP. The bigger the measure, the more trade there is relative to the size of the country, and the more the country is considered open to trade. By this measure Canada is much more open to trade than the US. In fact, of the twenty-two countries, the US has the second lowest openness quotient in 1985. Canada has one of the highest. This measure of openness, however, ignores relative geographic factors that account for a lot of observed trade flows. The gravity equation accounts for geography and so border effects also account for geographic factors. Comparing the two measures shows some large inconsistencies. For instance, the US was sixth highest and Canada only thirteenth in terms of border effects. For the data I used, the correlation between the two measures for the twenty-two countries was almost zero for the whole sixteen years. The problem is whether one can trust these country-specific border effects to give an accurate and comprehensive measure of openness. I would be hesitant to use my measures of border effects at this point. However, if internal distance measures were more accurately identified, then I would feel much more confident in using country-specific border effects in other contexts.

A second benefit of improved internal distance measures is that estimates of industry-specific border effects also become more legitimate. One can imagine many situations where the degree of international integration in an industry is an important determinant of firm or government behaviour. We would not expect them to exhibit the same behaviour if industries differ in trade intensity. I have already identified environmental regulation as one such example. One can also imagine foreign direct investment, or research and development investments, as being correlated, in some fashion, to industrial openness. Having accurate and comprehensive measures of openness over time and across sectors allows one to test alternative theories.

The second kind of extension is to explore some of the results found in the chapter in more detail. I can think of two projects.

The first is to explore the relationship between access to alternative markets and density of exports. The data revealed that exports tended to rise if the exporter had greater access to markets. Imports, on the other hand, fell if the importer had greater access to markets. The asymmetric results were unexpected. I suggested this is could be tied to the concept of Home Market Advantage. The hypothesis is that countries can gain a comparative advantage if they have a large home market. They would attain lower costs due to economies of scale and so produce and export more. The original formulation of that problem supposed the (relative) size of the home market was the critical factor. Evidence was limited but did support the hypothesis (Weder, 1997). However, countries have partners that also contribute to demand for home products. To be sure, foreign demand is biased inward, but should not be ignored in calculating home demand. This is what the measure ALTh does. We could augment the Home Market hypothesis to incorporate foreign demand as a contribution to home market demand.

The second project is to look at how the concentration of production has proceeded over time. Krugman (1991) claims that measures of industrial concentration and interdependence are positively correlated. He shows that American States appear to be more diverse than European States. Production in the US is less homogenous with manufacturing sectors clustered geographically. He takes this as evidence that deeper US economic integration has induced a dispersion of production. Firms have moved to locations that offer them location specific advantages. European countries, on the other hand, appear more alike as each has had to satisfy home consumption through local production. Krugman predicts that European countries will diverge as comparative advantages begin to draw production into geographic clusters. However, similar dispersion measures of the countries I use show that the OECD countries are actually becoming less diverse; each is becoming more like their neighbor. At the same time though, individual industries, as indicated in Table 4.13, are becoming more geographically concentrated. These two results are consistent with both increased intra-industry trade and convergence of national economies. These are preliminary results only and need to be more systematically studied.

BIBLIOGRAPHY:

Anderson, Kym and Richard Blackhurst (1995), "Trade, the Environment and Public Policy" in *The Greening of World Trade Issues*, edited by Kym Anderson and Richard Blackhurst, University of Michigan Press, Ann Arbor, Mich. pp 3-22.

Barbera, Anthony J. and Virginia D. McConnell (1990), "The Impact of Environmental Regulations on Industry Productivity: Direct and Indirect Effects", *Journal of Environmental Economics and Management*, vol 18, pp. 50-65.

Barnett, A H, (1980), "The Pigouvian Tax Rule under Monopoly", *The American Economic Review*, Vol. 70, No. 5, pp. 1037-41.

Barrett, Scott, (1994), "Strategic Environmental Policy and International Trade", *Journal of Public Economics*, 54, pp. 325-38.

Baumol, William J, John C Panzar, and Robert D Willig, (1982), *Contestable Markets and the Theory of Industry Structure*, Harcourt Brace Jovanovich Publishers New York.

Besanko, David (1987), "Performance Standards versus Design Standards in the Regulation of Pollution", *Journal of Public Economics*, Vol. 34, pp. 19-44.

Bhagwati, Jagdish (1996), "The Demands to Reduce Domestic Diversity among Trading Nations", in *Fair Trade and Harmonization: Prerequisite for Free Trade?*, Vol 1: Economic Analysis, edited by Jagdish Bhagwati and Robert E. Hudec, MIT Press, Cambridge Mass., USA. Pp 9-40.

Brander, Jim and Barbara Spencer (1985), "Export Subsidies and Market Share Rivalry", *Journal of International Economics* 18:83-100.

Brander, Jim (1995), "Strategic Trade Policy", in *Handbook of International Economics, vol III,* edited by G. Grossman and K. Rogoff, Elsevier Science B.V.

Buchanan, James M. and Gordon Tulock, (1975), "Polluters' Profits and Political Response: Direct Controls Versus Taxes", *The American Economic Review*, Vol. 65, No. 1, p.p. 139-47.

Chen, Natalie (2000), "Intra-National versus International Trade in the European union: Why do National Borders Matter", unpublished mimeo, ECARES, Université Libre de Bruxelles.

Cooper, Russell, and Raymond Riezman (1989), "Uncertainty and the Choice of Trade Policy in Oligopolistic Industries", *The Review of Economic Studies*, 56, 129-140.

Copeland, Brian (1992), "Taxes versus Standards to Control Pollution in Imperfectly Competitive Markets", unpublished mimeo, University of British Columbia.

Cropper, Maureen L., and Wallace E. Oates (1992), "Environmental Economics: A Survey", *Journal of Economic Literature*, 30:675-740.

Deardorf, Alan V. (1998), "Determinants of Bilateral Trade: Does Gravity Work in the Neoclassical World", in *The Regionalization of the World Economy*, edited by Jeffrey Frankel, University of Chicago Press, Chicago, pp. 7-32.

Dewees, Donald N. (1983), "Instrument Choice in Environmental Policy", *Economic Inquiry*, Vol 21, pp 53-71.

Eichengreen, Barry and Douglas A. Irwin (1998), "The Role of History in Bilateral Trade Flows", in *The Regionalization of the World Economy*, edited by Jeffrey Frankel, University of Chicago Press, Chicago, pp. 33-62.

Esty, Daniel C. (1994), *Greening the GATT: Trade, Environment, and the Future,* Institute for International Economics, Washington, DC.

European Commission, (1994), *Potential Benefits of Integration of Environmental and Economic Policies, An Incentive-Based Approach to Policy Integration.* Graham and Trotman and Office for Official Publications of the European Communities.

Feenstra, Robert C., James A. Markusen, and Andrew K. Rose (1998), "Understanding the Home Market Effect and the Gravity Equation: The Role of Differentiating Goods", NBER Working Paper 6804.

Feenstra, Robert C., Robert E. Lipsey, Harry P. Bowen (1997), "World Trade Flows, 1970-1992, With Production and Tariff Data", NBER Working Paper 5910.

Frankel, Jeffrey A. (1997), *Regional Trading Blocs in the World Economic System*, Institute for International Economics, Washington.

Golombek, Rolf and Arvid Raknerud (1997), "Do Environmental Standards Harm Manufacturing Employment", *Scandinavian Journal of Economics*, Vol 99(1), pp 29-44.

Goulder, Lawrence H., 2000, "Environmental Policy Making in a Second-Best Setting" in *Economics and the Environment: Selected Readings, Fourth Edition*, edited by Robert N. Stavins, W.W. Norton and Company, New York, pp 396-427.

Gruenspecht, Howard K. and Lester B. Lave (1989), "Economics of Health, Safety, and Environmental Regulation", in *Handbook of Industrial Organization, Vol 2*, Schmallensee and Willig editors, North Holland Ltd., New York, pp. 1508-50.

Hansson, Gote (1990), *Harmonization and International Trade*, Routledge, London and NY,

Harrigan, James (1996), "Openness to Trade in Manufactures in the OECD", *Journal of International Economics*, VOL. 40, pp. 23-39.

Harrigan, James (1993), " OECD Imports and Trade Barriers in 1983", *Journal of International Economics*, VOL. 35, pp. 91-111.

Haveman, Jon and David Hummels (1997), "What Can We Learn From Bilateral Trade? Gravity and Beyond", mimeo, Centre for International Business Education and Research, Purdue University.

Head, Keith and Thierry Mayer (2000), "Non-Europe: The Magnitude and Causes of Market Fragmentation in the EU", unpublished mimeo, University of British Columbia.

Helfand, Gloria (1991), "Standards versus Standards: The Effects of Different Pollution Restrictions", *The American Economic Review*, Vol. 81, No. 3, pp. 622-34.

Helliwell, John (1996), "Do National Borders Matter for Quebec's Trade?", *Canadian Journal of Economics*, XXIX, NO. 3, pp. 507-22.

Helliwell, John F (1998), *Do National Borders Matter?* Brookings Institution Press, Washington.

Helliwell, John F (2000), "Linkages Between National Capital Markets: Does Globalization Expose Policy Gaps?" unpublished mimeo, University of British Columbia.

Helliwell, John F. and Genevieve Verdier (1999), Comparing Intraprovincial and Interprovincial Trade Intensities, (Paper presented to the Annual Meetings of the Canadian Economics Association, Toronto).

Helpman, E. and P. Krugman (1985), *Market Structure and Foreign Trade: Increasing Returns, Imperfect Competition, and the International Economy*, MIT Press, Cambridge, MA.

Hwang, H. S., and Craig T. Schulman (1993), "Strategic Non-Intervention and the Choice of Trade Policy for International Oligopoly", *Journal of International Economics*, 34, 73-93.

Jaffe, Adam B., Steven R. Peterson, Paul R. Portney, and Robert N. Stavins (1995), "Environmental Regulation and the Competitiveness of U.S. Manufacturing: What Does the Evidence Tell Us?", *Journal of Economic Literature*, Vol XXXIII (March 1995), pp. 132-63.

Kalt, Joseph P. (1985), "The Impact of Domestic Environmental Regulatory Policies on US International Competitiveness", *Harvard Energy and Environmental Policy Center Discussion Paper* E-85-12

Katsoulacos, Yiannis, and Anatasasios Xepapadeas, (1995), "Environmental Policy under Oligopoly with Endogenous Market Structure", *Scandinavian Journal of Economics*, vol 97(3), pp. 411-20.

Krugman, Paul (1991), *Geography and Trade*, Leuven University Press, Belguim and MIT press, Cambridge, Massachusetts.

Markusen, James R., Edward R. Morey, and Nancy Olewiler (1995), "Competition in Regional Environmental Policies when Palnt Locations are Endogenous", *Journal of Public Economics*, 56, pp 55-77.

Mathewson, G.F., and R.A. Winter (1984), "An Economic Theory of Vertical Restraints", *Rand Journal of Economics*, 15(1), p.p. 27-38.

McCallum, John (1995), "National Borders Matter: Canada-US Regional Trade Patterns", *The American Economic Review*, VOL. 85 NO. 3, pp. 615-23.

Nitsch, Volker (1997), "National Borders and International Trade: Evidence From the European Union", mimeo, Bankgesellschaft Berlin.

Porter, Michael E. (1990), *The Competitive Advantage of Nations*, The Free Press, New York.

Porter, Michael E. and Claas van der Linde (2000), "Toward a New Conception of the Environment-Competitiveness Relationship" in *Economics and the Environment: Selected Readings, Fourth Edition*, edited by Robert N. Stavins, W.W. Norton and Company, New York, pp 180-202.

Potier, Michel (1997), "Integrating the Environment and the Economy" in *Sustainable Development: OECD Policy Approaches for the 21st Century*, pp. 15-28, OECD, Paris.

Rose, Andrew K. (1999), "One Money, One Market: Estimating The Effect of Common Currencies on Trade", NBER Working Paper 7432.

Shivakumar, Ram (1993), "Strategic Trade Policy: Choosing Between Export Subsidies and Export Quotas under Uncertainty", *Journal of International Economics*, 35, pp 169-83.

Simpson, R. David and Robert L. Bradford, III (1996), "Taxing Variable Cost: Environmental Regulation as Industrial Policy", *Journal of Environmental Economics and Management*, vol 30, pp. 282-300.

Spulber, Daniel F. (1985), "Effluent Regulation and Long-run Optimality", *Journal of Environmental Economics and Management*, vol 12, pp. 103-16.

Stein, Ernesto and Diana Weinhold (1997), "Canadian US Border Effects and the Gravity Model of Trade", mimeo, Inter-American Development Bank.

Stewart, William (1999), "Attractiveness as a Measure of Alternative Trading Opportunities", mimeo, University of British Columbia.

Tirole, Jean (1990), *The Theory of Industrial Organization*, MIT Press Massachusetts.

Ulph, Alistair (1996), "Environmental Policy and International Trade when Governments and Producers Act Strategically", *Journal of Environmental Economics and Management*, Vol 30, p.p. 265-81.

(1994), "Environmental Policy and International Trade: A Survey of Recent Economic Analysis", *Nota Di Lavoro* 53.94.

(1992), "The Choice of Environmental Policy Instruments and Strategic International Trade" in *Conflicts and Cooperation in Managing Environmental Resources*, Rudiger Pethig, editor, Springer-Verlag, Berlin.

Verdier, Thierry (1993), "Strategic Trade and the Regulation of Pollution by Performance or Design Standards", *Nota Di Lavoro* 58.93.

Weder, Rolf (1997), "Comparative Home-Market Advantage: An Empirical Analysis of British and American Exports", UBC discussion paper 97-14.

Wei, Shang-Jin (1996), "Intra-National versus International Trade: How Stubborn are Nations in Global Integration?", NBER Working Paper 5531.

Wilson, John (1996), "Capital Mobility and Environmental Standards: Is There a Theoretical Basis for a Race to the Bottom?" in *Fair Trade and Harmonization: Prerequisites for Free Trade?* Edited by Jagdish Bhagwati and Robert E. Hudec, MIT Press, Cambridge, Mass. Pp 393-427.

Wolf, Holger C. (1996), "Intra- and Inter-State Trade in the US", mimeo, Stern Business School.

APPENDIX I: ANALYTICAL RESULTS

This appendix shows analytical results used for the simulation in Chapter III, Sections 3.5 and 3.6. All calculations were found using MAPLE V.

MODEL PARAMETERIZATION:

- **Emissions:** $\mathbf{e(q,a) = q - a}$.
- **Costs:** $\mathbf{C(q,a)= c\ q + d\ (a^2)/2}$.
- **Damage:** $\mathbf{D(e) = b\ e^2}$.
- **Demand** $\mathbf{P(Q)= K - s\ (Q)}$ where $Q = (q^H + q^F)$ and $K > c$.

<u>**CASE (DD):**</u> Both use Design Standards. This yields equilibrium outputs: $\mathbf{q^* = q^H = q^F = (K-c)/(3s)}$ which are independent of targets and abatement costs. Each regulator chooses emission targets of $\mathbf{E^*=d(K-c)/[3s(d+2b)] = q^*[d/(d+2b)] < q^*}$. These targets are always binding ($E^*<q^*$). They fall (become stricter) as the marginal abatement schedule falls or if marginal damages rise. If $\boldsymbol{d\to\infty}$, or $\boldsymbol{b\to 0}$, then the emissions approach the unregulated industry's emissions of $\mathbf{(K-c)/3s}$.

<u>**CASE (EE)**</u>: Both use Emission Standards. Each target is restricted above by (K-c)/3s: emissions of an unregulated industry. This yields Home output: $\mathbf{q^H= \alpha[(K-c)(s+d) + (2s+d)dE^H -s\ d\ E^F]}$ where $\alpha = (2s+d)/[(2s+d)^2 - s^2]$. Equilibrium outputs are no longer independent of targets in either country. Emissions become strategic substitutes. The symmetric Nash Equilibrium emissions are $\mathbf{E^*=(K-c)(d^2+ 4sd + 4\ s^2)d/\gamma}$ where $\boldsymbol{\gamma}\mathbf{=(18bs^3+30bds^2+14bd^2s+2bd^3+9s^3d+11s^2d^2+3d^3s)}$.

Note that, as $\boldsymbol{d\to 0}$, $\mathbf{E^*\to 0}$. As $\boldsymbol{d\to\infty}$, $\mathbf{E^*\to(K-c)/(2b+3s) < (K-c)/3s}$. High values or low values of d lead to binding emissions.

If $\boldsymbol{b\to\infty}$, $\mathbf{E^*\to 0}$. As $\boldsymbol{b\to 0}$, $\mathbf{E^* \to[((K-c)/s]\ (d^2+ 4sd + 4\ s^2)/(9s^2+11sd+3d^2) > (K-c)/3s}$: countries will not bind emissions when emissions are non-damaging.

Now consider the race to the bottom only. We let $\mathbf{E^h = E^f \le (K-c)/3s}$ which is the unregulated emissions and find conditions for this to hold. Note that this is not the same as being fully unregulated so reduces the range in which a race occurs. $\mathbf{E^h = E^f = (K-c)/3s}$ are best responses only if $\mathbf{b \le ds^2/(6s^2+8ds+2d^2)}$. Two comments. First, there are many parameters for which this is satisfied. Second, the race to the bottom is an equilibrium outcome ONLY IF marginal damages are relatively small. We would never see a race if emissions are very toxic or damaging. The maximum value for b occurs at $\mathbf{d = (s\sqrt{3})}$. Therefore, if $s = 1$ and $b \geq 0.0670$ or if $s = 2$ and $b \geq 0.1340$, then the Nash equilibrium always generates binding targets

<u>CASE (DE)</u>: Home uses Design Standards and Foreign uses Emission Standards. This yields each firm's best response functions: $\mathbf{q^H = [(K\text{-}c)/s - q^F]/2}$ and $\mathbf{q^F = [(K\text{-}c + dE^F)\text{-}sq^H]/(2s+d)}$. Notice now that Foreign's outputs, hence welfare, are independent of Home's target. Home's welfare, on the other hand, is very much affected by Foreign's targets. Note the range of parameters for which (P) yields non-binding targets rises since Foreign is effectively "non-regulated" for all parameter values. This means that it is more likely that countries will choose to deregulate its own industry under P if the other is unregulated.

<u>CASE (ED)</u>: Home uses Emission Standards and Foreign uses Design Standards. This is symmetric to CASE (DP)

<u>CASE (TT)</u>: Home and Foreign uses Emission Charges. Denote $\mathbf{T^h}$ and $\mathbf{T^f}$ are emission taxes in Home and Foreign. These are restricted to be non-negative. This restriction binds in some circumstances.

Since marginal costs are constant, Home abatement becomes $\mathbf{T^H/d}$. Output is $\mathbf{q^H = (K\text{–}c\text{–}2T^h + T^f)/3s}$. Domestic taxes reduce Home output. Note that output is independent of marginal abatement costs. In effect the firm has a two stage problem. Given the emission tax, it finds output that maximizes net revenues. Then it finds the abatement that minimizes abatement costs plus tax payments. A rise in *d* lowers abatement but not output.

Homes best response taxes become $\mathbf{T^H = d(K\text{-}c + T^F)(\text{-}sd+6bs+4bd)/\beta}$ where $\mathbf{\beta=(4sd^2+8bd^2+24bds+9s^2d+18bs^2)}$. Taxes become strategic complements if $\mathbf{b \geq sd/(6s+4d)}$. That is, if damages are high enough, then the more Home taxes their firms, the lower their output and so the more Foreign can tax their own firms. Otherwise, taxes will be substitutes. The symmetric equilibrium is $\mathbf{T^* = d(K\text{-}c)(6bs+4bd\text{-}ds)/(18bs^2+18bsd+4bd^2+9s^2d+5sd^2)}$.

As $\mathbf{d \rightarrow 0, T^* \rightarrow 0}$; if abatement is easy, a small tax reduces emissions to zero. Note that this is not a race to the bottom. Rather, emissions go to zero as T goes to zero since this lowers the firms net costs of emissions. However, as $\mathbf{d \rightarrow \infty}$, $\mathbf{T^* \rightarrow (K-c)(4b - s)/(5s+4b)}$ which is positive if and only if $\mathbf{b > s/4}$. High marginal abatement costs lead to unregulated firms if marginal damages are low enough. Otherwise, taxes in equilibrium are positive.

As $\mathbf{b \rightarrow \infty}$, $\mathbf{T^* \rightarrow (K-c)}$ which is positive. Taxes are always positive for high marginal damages. On the other hand, as $\mathbf{b \rightarrow 0}$, $\mathbf{T^* \rightarrow -(K-c)d/(9s+5d)}$ which is negative. For low marginal damages, countries wish to subsidize production by paying firms to pollute! This isn't as outlandish as it first appears since this is the analog to an export subsidy studied by Brander and Spencer (1985). It promotes output. This form of "export" subsidy is not possible under (PP) and assumed away when taxes are non-negative.

Now consider only the race to the bottom where $\mathbf{T^* = T^H = T^F = 0}$. This only occurs when $\mathbf{b \leq sd/(6s+4d)}$. Three comments.

- First, we get the race to the bottom in taxes ONLY IF taxes are strategic substitutes. Lower taxes become reinforced.
- Second, the limit of this condition as $\mathbf{d \rightarrow \infty}$ is $\mathbf{s/4}$. Increasing marginal abatement costs *will not* preclude the race to the bottom as it did under (PP). One way to see this is to consider a low d where the equilibrium taxes are already zero. Now raise d. The firm does not need to respond. It does not reduce abatement, emissions, or output. Consequently, once the regulator eliminates the emission tax, any further rise in d becomes irrelevant and so does not create any incentive to push up taxes. Under (PP), a rise in d reduced the willingness of regulators to behave opportunistically and so lead to binding targets.
- Third, the greater the demand elasticity, which is a function of s, the more likely the race. Here, a small tax has big output effects so motivates the regulator to reduce taxes. As $\mathbf{s \rightarrow 0}$, $\mathbf{T^* \rightarrow (K-c) > 0}$: lower elasticities create binding taxes.

APPENDIX II: PROOFS

Proposition 2.1: *The Optimal Emission Target is slacker under Monopoly than under Perfect Competition.*

Proof: Relies on downward sloping demand curve.

1 Let E* be the optimal Emission target under Perfect Competition.
2 At E* we have MAC(Q, E*) = MD(E*): marginal pollution damages are equal to marginal abatement costs where Q is the industry output given E*.
3 Now let the market be controlled by one firm facing the same industry emission target E*.
4 Since Demand is downward sloping, we have monopoly output below the perfectly competitive market.
5 By assumption, MC is rising and price falling in output implying that (P-MC) at the monopoly output is larger than MAC at the competitive output.
6 The cost to society of raising emissions is equal to (P-MC) under monopoly. This is the lost surplus as a result of decreased industry output.
7 Hence, under monopoly (P-MC) > MD(E*).
8 This implies that the optimal Emission target under monopoly must rise since MD is rising in E and (P-MC) falling. The slacker E generates higher output.

Proposition 2.2 (Sufficient conditions)**:** *For any given number of firms and any binding target, Design Standards (Potentially) Pareto Dominate Emission Standards as long as the market price is above Marginal Social Compliance Costs at the unregulated output, $C^E_q(q^D,a^D)$.*

Proof: Relies on output being lower than the social optimum.

1. Fix the emission target, market demand, and number of firms in the industry. Recall that market price is decreasing in industry output and marginal compliance costs are non-decreasing in output.
2. Consider the equilibrium output and abatement under Design Standards. Denote $C^E_q(q^D,a^D)$ as the marginal costs associated with output q^D and abatement a^D for each firm but using Emission Standards rather than Design Standards to implement the target.
3. Assume the market price under Design standards is above this level: $P^D(q^D) \geq C^E_q(q^D,a^D)$
4. Since price exceeds private (hence social) marginal costs and price is decreasing in output, we must have output below the social optimum under Design standards: a rise in output would raise social benefits (area under the demand curve) more than social costs (production and compliance costs).
5. Denote the social optimal output, given target E, as q* , such that $P^* = C^{E^*}_q(q^*,a^*)$.
6. From Proposition 6 we have $q^E \leq q^D$ hence $P^E \geq P^D$.
7. By assumption we also have $C^E_q(q^D,a^D) = C^E_q(q^D,a^P) \leq C^E_q(q^P,a^P)$.
8. Hence the wedge between market price and marginal abatement costs rise as we move to Emission Standards from Design Standards. In this respect Emission standards worsen the output distortion associated with the Cournot competition.
9. Since social welfare falls the further we are from q* we must have $W^D \geq W^E$.

10. Note that if $P^E > P^* > P^D$ then output under Design standards exceeds the social optimum but can still generate $W^D \geq W^E$. □

Proposition 2.3: *Under Perfect Competition:*

a) $E^{*E} \leq E^{*D}$ *and*

b) $W^{*E} \geq W^{*D}$

Proof: (a) Relies on increasing marginal abatement costs.

1 Let E^{*E} be the optimal Emission target under Perfect Competition.
2 At E^{*E} we have $MAC(Q^E, E^{*P}) = MD(E^{*E})$: marginal pollution damages are equal to marginal abatement costs where Q^E is the industry output given E^* .
3 Since Design Standards are a *de facto* fixed cost, output is identical to the unregulated output Q^U.
4 Imposing E^{*E} as the Design Target implies that $MAC(Q^U, E^*) > MAC(Q^E, E^*)$ since marginal abatement costs are rising in abatement and abatement is rising as $Q - E$ rises.
5 Hence, $MAC(Q^U, E^*) > MD(E^{*E})$.
6 This implies E must rise lowering $MAC(Q^U, E)$ and raising $MD(E)$.

(b) Relies on Emission Standards dominating Design for a given target.

1 Let E^{*D} be the optimal Design target under Perfect Competition.
2 At E^{*D} we have $MAC(Q^U, E^{*D}) = MD(E^{*D})$.
3 However, Q^U is above the social optimum defined in Proposition 2.
4 Output under Emission Target with target E^{*D} is the social optimum.
5 Hence welfare, given E^{*D}, is higher using Emission Standards than Design Standards.
6 By choice of targets, Emission regulations cannot do worse than choosing E^{*D}, hence welfare cannot be lower under Perfect Competition.

Proposition 2.4: For *$N \geq 1$ firms. If $MC^E(Q^U, E^{*P}) \leq P(Q^U)$, then*

a) $E^{*E} \geq E^{*D}$ *and*

b) $W^{*D} \geq W^{*E}$

Proof: (a) Relies on increasing marginal abatement costs

1 Let E^{*E} be the optimal Emission target under Cournot Competition and $MC^E(Q^U, E^{*E}) \leq P(Q^U)$. Recall that $MC^E(Q^U, E^{*E})$ is the true social marginal compliance cost given the target E^{*E}.
2 The choice of E^{*E} solves $MD(E^{*E}) = (P(Q^E) - MC(Q^E))$ where Q^E is the industry equilibrium output given the industry target and abatement technologies.
3 Since MC rises and Price falls with output we have $(P(Q^E) - MC(Q^E)) > (P(Q^U) - MC(Q^U))$.
4 By assumption in (1) we have $(P(Q^U) - MC(Q^U)) \geq MAC(Q^U, E^{*E})$.
5 Therefore $MD(E^{*E}) > MAC(Q^U, E^{*E})$
6 MD are rising in E so by choice of E^{*D} we must have $MD(E^{*D}) < MD(E^{*E})$
7 Hence $(E^{*E}) > (E^{*D})$

(b) Relies on Proposition 2.

1 Let E^{*E} be the optimal Emission target under Cournot Competition.
2 By proposition 2 we have $W^D \geq W^E$ for target E^{*E}.
3 By choice of targets, Design regulations cannot do worse than choosing E^{*E}, hence welfare cannot be lower under Cournot Competition.
4 Note that the critical assumption is that unregulated output is below the social optimum given E^{*E}. If it is above, then we cannot say unambiguously that design Standards are better. They may be.

Proposition 2.5: *Let emission targets be binding and $C_{qa}<0$. Then:*
(a) (Design Standards) $C_q^D(q,a) < C_q^U(q,0)$, *and*
(b) (Emission Standards): $C_q^E(q,a) < C_q^U(q,0)$ *if* $C_{qa}(q,a) << 0$.

Proof: relies on strength of direct plus indirect effects of regulation.

1. By assumption, a binding Design Standard forces the firm to abate at level A. Hence its marginal compliance costs are $C_q^D(q,A)$.
2. Since $C_{qa} < 0$ we must have $C_q^D(q,A) < C_q^D(q,0) = C_q^U(q,0)$. With Design Standards there is no direct effect of regulations pushing up marginal compliance costs. Only the indirect effect is present and this reduces MC^D.
3. A binding emission standard yields marginal compliance costs of : $C_q^E(q,a) = C_q(q,a) - C_a(q,a)\,[e_q(q,a) / e_a(q,a)]$.
4. The direct effect on marginal costs of the regulation is $C_a(q,a)\,[e_q(q,a) / e_a(q,a)]$. This is positive.
5. So $C_q^E(q,a)$ is less than $C_q^U(q,0)$ only if the indirect effect of abatement is strong. That is, if $C_q(q,a)$ falls more than $C_a(q,a)\,[e_q(q,a) / e_a(q,a)]$.

Propositions 2.6 and 2.7: *Suppose we have $N \geq 1$ and $C(q,a) = C(q) + D(a)$. For an arbitrary target we have:*

a) *Output:* $Q^O \leq Q^E \leq Q^K \leq Q^D$,
b) *Abatement:* $A^E \geq A^K \geq A^D \geq A^O = 0$,
c) *Profit:*
   i. $\Pi^E \geq \Pi^K \geq \Pi^D$.
   ii. *For n small:* $\Pi^E \geq \Pi^O$
   iii. *For N large:* $\Pi^O > \Pi^E$
d) *Welfare:*
   i. $W^K \geq W^E$ *when* $P > C_q^K(q,a)$.
   ii. *Welfare:* $W^E \geq W^O$
   iii. *At the optimal target we have:* $W^{*K} \geq W^{*E}$ *and* $E^{*K} \leq E^{*E}$ *when* $P > C_q^K(q,a)$.
   iv. *At the optimal targets we have:* $W^{*E} \geq W^{*O}$ *and* $E^{*E} \leq E^{*O}$

(a) (output): $Q = q^O \leq q^E \leq q^K \leq q^D = q^U$ *for each firm*

Proof: Relies on relative effects on marginal costs.

1. Fix the number of firms, market demand, and emission target for each firm. Each firm's marginal revenue schedule is now fixed so any differences in output can only be associated with different marginal cost curves. It is sufficient to show that, for any q $\geq$ q(E), marginal costs are increasing as we move from design to concentration to emission to output constraints.
2. $q^D = q^U$: By construction, a binding Design constraint forces the firm to install abatement level A but places no other constraints on the firm. By assumption, production costs are independent of abatement. Therefore, the firms' marginal cost schedules are identical to unregulated firms. Hence the firms' outputs are the same as unregulated firms. The assumption that profits are positive under regulation ensures that no firms exit.
3. $q^K \leq q^D$: The change in total costs of raising output under a concentration standards is $C_q + C_a$ (da/dq). (da/dq) is positive since any rise in output must entail a rise in abatement sufficient to meet the concentration requirement. Since C_q is independent of abatement and C_a is positive, we must have $C_q + C_a \,(da/dq) > C_q$.
4. $q^E \leq q^K$: From each firm's first order conditions we get marginal compliance costs, under emission and concentration standards, of $[C_q - C_a\, e_a/e_q]$ and $[C_q - C_a\, e_a/e_q + K\, C_a/e_q]$ respectively. Since K>0, C_a>0 and e_a<0 we must have higher marginal compliance costs under emission standards. This forces firms to lower output given their downward sloping marginal revenue function.
5. $q^O \leq q^E$: By assumption, the binding emission target implies that $q^O = q(E) < q^U$. Production costs are convex and revenue concave hence the firm's profit function is also concave. This means that profits do not rise (and generally fall) for outputs below the output constraint q(E). Any output at, or below, q(E) satisfies the firm's emission constraint but offers lower profits. Hence, the firm's optimal output choice will never fall below q^O. It can, and generally will, choose an output level above this. □

(b) (abatement): $0 = a^U = a^O \leq a^E \leq a^K \leq a^D$ *for each firm,*

Proof: relies on output differences but identical targets across standards.

1. An unregulated firm does not abate since it raises costs but not revenue. Therefore a^U=0.
2. Similarly, output constraints do not require firms to abate so they do not.
3. By assumption, each firm, under each constraint E, K, or D emits the same level of pollution despite different output levels.
4. The higher the output the, higher the abatement required to attain the same target.
5. Hence, as $q^O \leq q^E \leq q^K \leq q^D$, we must have the converse for abatement. □

(c) Profit: $\Pi^E \geq \Pi^K \geq \Pi^D$. *and n small:* $\Pi^E \geq \Pi^O$ *with N large:* $\Pi^O > \Pi^E$

MONOPOLY PROFITS: relies on revealed preferences over constraint sets.

1. Profits are highest if unregulated: Any combinations of output and abatement are feasible options. In particular it can choose any combination that satisfies each regulation. An unregulated firm could choose to, but does not, abate. Hence, the unregulated monopolist must receive higher profits in general.
2. Under regulation profits under emission constraints are highest: by construction the outputs and abatement under each constraint also satisfy the emission constraint since

they achieve the same target. Hence, the firm's choice under a emission constraint cannot do worse than any of the other choices.

3. Profits under concentration standards are higher than under design standards: by Proposition 1 we have $q^K \leq q^D$ and $a^K \leq a^D$. Also, the firm abates so that both constraints are just binding. This yields $e(q^D;a^D)/q^D \leq e(q^K,a^K)/q^K = K$ since $e(q^D,a^D) = e(q^K,a^K)$. Hence the design constraint satisfies the concentration constraint. Hence, the firm cannot do worse under a concentration standard than a design standard.
4. By construction, we have profits of an unregulated monopolist above those of either a firm regulated by Output constraints or by Design Standards. Profits between the two forms of regulation are not directly comparable. However, if we assume abatement costs are smaller than the increase in profits then Design Standards yield higher profits.

OLIGOPOLY PROFITS: *Let n firms each face the same binding emission target. Let* $n\, q^O$ *and* $n\, q(E)$ *be above the joint profit maximizing level of output. Then :* $\pi^O \geq \pi^E \geq \pi^K \geq \pi^D$ *. Furthermore* $\pi^O \geq \pi^U \geq \pi^D$ *with* $\pi^E \geq \pi^U$ *and* $\pi^K \geq \pi^U$ *in some cases.*

1. $\pi^O \geq \pi^U$: Output constraints raise profits above the unregulated market. By construction, the competition between firms leads to production in excess of the joint profit maximizing level. Output constraints reduce joint output without forcing firms to abate. Hence, as long as the target is too strict ($n\, q^O$ much below the joint optimum) , output will fall closer to the joint optimum and so raise profits.
2. $\pi^U \geq \pi^D$. By construction, output levels are the same but firms must abate under Design Standards. Hence they get the same revenue but incur higher costs and so have lower profits.
3. $\pi^O \geq \pi^E$: As above, output constraints reduce output but do not raise abatement. This yields $q^O \leq q^E$ and $0 = a^O \leq a^E$. Output under the output constraint is closer to the joint optimum so even if the firm didn't have to abate, output constraints would still yield higher profits.
4. $\pi^E \geq \pi^K \geq \pi^D$: By Proposition 1 we have $q^E \leq q^K \leq q^D = q^U$ and $0 \leq a^E \leq a^K \leq a^D$. Reductions in output from the unregulated case, for a given abatement level, will raise profits since this moves total output towards the joint optimum. Lower abatement, for a given output, also raises profits. Together, emission standards, with their lowest output and abatement, yield highest profits.
5. $\pi^E \geq \pi^U$: By construction, emission standards reduce output closer to the joint maximizing level. If the firm were rebated the costs of abatement as a lump sum, it's profits would rise above the unregulated case. Therefore, as long as the total abatement costs are small, its profits can rise. The issue is whether the firm's average markup falls. We know that if the demand facing the firm is elastic, then a rise in marginal costs raises prices but lowers its marginal markup. However, marginal costs only rise over the range $q \geq q(E)$ so average markups, over the entire range of output, could rise even though marginal markups fall.
6. $\pi^K \geq \pi^U$: Similar to (5) above except marginal costs rise throughout the range of output. As long as the rise in marginal costs is smaller for lower outputs average markups could rise. Note, however, that the rise in marginal costs is less and so the rise in price is also less. This makes it more difficult to raise profits under concentration standards.

Welfare:

(d) *for a given target* $W^K \geq W^E$ *when* $P > C_q^K (q,a)$.

(e) *At the optimal target we have:* $W^K \geq W^E$ *and* $E^K \leq E^E$ *when* $P > C_q^K (q,a)$.

Proof is identical to Proposition 4 so is omitted.

(d) *For a given target:* $W^E \geq W^O$

Proof: Relies on too little output under Output Constraints.

1 Begin under the assumption that MAC = $+\infty$.
2 Hence $Q^O = Q^E$ where Q^E is the industry output under Emission Standards that attains target E and $e(Q^O) = E$.
3 This implies identical output, abatement, emissions, and welfare independent of the number of firms.
4 Now let MAC fall. This has zero effect on social welfare under Output Constraints.
5 With Emission constraints firms can raise output if desired.
6 As long as market price is above (MC + MAC) evaluated at Q^O, social surplus rises.
7 Since (6) holds for Emission Standards, we musts have higher Social Welfare.

(e) *At the optimal targets we have:* $W^{*E} \geq W^{*O}$ *and* $E^{*E} \leq E^{*O}$

Proof: Relies on Emission Standards dominating Output Standards for a given target.

1 From (d) above we have $W^{*E} (E^{*E}) \geq W^{*E} (E^{*O}) \geq W^{*D} (E^{*O})$
2 Now, impose E^{*E} using both standards.
3 We have $(P - MC) \geq 0$ evaluated at Q^E less than $(P - MC)$ evaluated at Q^O since $Q^O \leq Q^E$.
4 By choice of E^{*E} and E^{*O} we have $MD(E^{*E}) = [P(Q^E) - MC(Q^P)] \geq [P(Q^O) - MC(Q^0)] = MD(E^{*O})$
5 Hence $MD(E^{*E}) \geq MD(E^{*O})$ and therefore $E^{*E} \leq E^{*O}$.

Lemma 3.1: *For a given output, marginal compliance costs rise as the emissions target falls (becomes more stringent) as long as the efficiency of abatement does not increase strongly with decreases in output.*

Proof:

1. The firm's first order necessary condition for an interior solution under a binding emission standard implies a marginal compliance cost of: $C^h_q(q^h,a^h) - C^h_a(q^h,a^h) [e^h_q(q^h,a^h) / e^h_a(q^h,a^h)]$. For a given output, a reduction in the emission target requires the firm to raise abatement. We need to show that a rise in abatement raises marginal compliance costs. This is not difficult.
2. By assumption $C_{qa} = 0$ so only the induced abatement costs of attaining the emission target matters.
3. This induced cost has two components. There is the direct effect of having to raise abatement: $\{-C^h_{aa}(*) [e^h_q(*) / e^h_a(*)]\}$ which is positive since e_a is negative and C_{aa} is positive. The indirect costs can be split into two components as well: $\{-C^h_a(*) [e^h_{qa}(*) / e^h_a(*)] + C^h_{aa}(*) e^h_q(*) e^h_{aa}(*)/[e^h_a(*)]^2\}$.
4. The second term in (3) captures the change in abatement efficiency as abatement rises. This term is non-negative since, by assumption, the marginal efficiency of abatement falls as abatement rises ($e^h_{aa}(*) \geq 0$). So forcing the firm to abate more induces an indirect rise in cost.

5. The first term in (3), however, is ambiguous since $e_{qa}(*)$ is unsigned. If e_{qa} is non-negative (the efficiency of abatement is higher at higher output levels) then the term is also non-negative and marginal compliance costs cannot fall with tighter emission targets. If it is non-positive, (ie. higher output lowers the efficiency of abatement) then the term is non-positive since e_a is negative. As long as this is not too strong the other two terms will dominate and marginal compliance costs rise.
6. Hence, as long as decreases in output do not raise the efficiency of abatement too much, then a rise in abatement raises marginal compliance costs. Hence a stricter emission target raises the firm's marginal costs of compliance. □

Proposition 3.1*: Optimal targets under Design Standards set marginal compliance costs equal to marginal pollution damages and so are an Environmentally Optimal Standard (EOS).*

Follows from definition of EOS and the fact that $dq^h/de^h = 0$.

Proposition 3.2: *If Foreign uses Design Standards, then Home's optimal emission target, under either standard, is independent of Foreign emission targets.*

Follows from the fact that $dq^f/de^f = 0$ hence q^f is only a function of q^h and not e^f..

Proposition 3.3*: Strategic Optimal Standards under Emission Standards set marginal compliance costs less than marginal pollution damages and so rise above the Environmentally Optimal Standard.*

See Barrett (1994) for the proof. p 330.

Lemma 3.2*: Home's Strategic Optimal Standards under Emission Standards are higher when Foreign uses Design Standards than when it uses Emission Standards*

This proof relies on two points. First, Design Standards are equivalent to a commitment to unregulated markets under Emission Standards. Second, the strategic effect is stronger if Foreign is unregulated.

1. Design Standards are equivalent to unregulated markets under Emission Standards.
   i) Marginal costs are identical, and minimized, under Design Standards or unregulated markets.
   ii) The Foreign regulator cannot alter those marginal costs by altering emission targets so has a "commitment" to unregulated markets.
2. The strategic effect is $[\pi^h{}_3(*)\, dq^f/dq^h]\, dq^h/dE^h$
   i) We need to consider the size of $[dq^f/dq^h]$
   ii) $[dq^f/dq^h]$ is determined by the slope of the foreign firm's reaction function.
   iii) The less marginal costs rise with output, the smaller the slope of the reaction function.
   iv) The smaller the slope of the reaction function, the more foreign output changes with a change in Home output.
   v) Binding regulations under Emission Standards raise marginal compliance costs and so raises the slope of foreign's reaction function.
   vi) Hence, if Foreign is unregulated, or uses Design Standards, its firm's output is more sensitive to Home output.
   vii) This raises the strategic effect.

3. 1 and 2 imply that Home's SOS rises given Foreign is using Design Standards.

Proposition 3.4: *Cooperatively set emission targets yield higher welfare under Emission Standards than under Design Standards.*

Proof: The proof is a revealed preference argument.

1 As constructed, output of the two firms is too high from a joint profit maximizing viewpoint. Firms, competing for market share, over-produce and so dissipate rents.
2 Acting cooperatively, regulators can choose to set targets at the same level as those chosen under Design Standards. Doing so yields the same pollution damage, but, as long as the targets are binding, will restrict output and so raise profits above those under Design Standards (recall that Design Standards are equivalent to unregulated markets in terms of output level).
3 Hence, regulators cannot do worse choosing Emission Standards cooperatively than choosing Design Standards (cooperatively).

Proposition 3.5: *Cooperatively set Emission Standards can raise Welfare even if pollution damages are zero.*

Proof: The proof relies on the fact that joint output is too high to maximize joint profits if firms are left unregulated. Since targets are set cooperatively, I will analyze the equivalent problem of a single country with two competing firms. See Bruneau (2000) or Buchanan and Tullock (1975) as well.

1. If there are no pollution damages, then welfare is simply the amount of rent extracted from the world market. With Emission Standards the optimal, cooperative, targets may be binding depending on whether the restriction in output raises revenues more than it raises abatement costs.
2. Consider the equivalent problem of a single country with two domestic firms that it can regulate. Profits are $(\pi^1 + \pi^2) = R(q^1+q^2) - C(q^1) - C(q^2) - D(q^1,E^1) - D(q^2,E^2)$ where D is abatement costs as a function of output and targets.
3. Suppose the regulator is contemplating a binding restriction on one firm. We need to show that $d(\pi^1 + \pi^2)/dE^1 < 0$ evaluated where E is just binding on the unregulated firms. The first derivative is $[R'(*) - C'(q^1) - D'(q^1,E^1)]dq^1/dE^1 - \partial D/\partial E^1 + R'(*)(\partial q^2/\partial q^1)\, dq^1/dE^1$.
4. By the envelop theorem this reduces to $R'(*)(\partial q^2/\partial q^1)\, dq^1/dE^1 - \partial A/\partial E^1$ since the bracketed term [] is zero.
5. R' is positive, $(\partial q^2/\partial q^1)$ is negative because outputs are strategic substitutes, dq^1/dE^1 is positive if E is binding, and $\partial A/\partial E^1$ is negative since a lower E requires more abatement for a given output. This gives the sum of a negative and a positive term, which is ambiguous. However, as long as the first term is larger in absolute value than the second, the sum is negative and a reduction in E (becoming binding) raises profits hence Welfare.
6. So, a binding target will reduce joint output, raising revenues and joint profits, as long as the increased abatement costs are small.

Proposition 3.6: *The Nash Equilibrium in non-strategic Emission targets yields higher Welfare than the Nash Equilibrium in Design targets. Furthermore, targets are also lower under non-strategic Emission Standards.*

The proof relies on the fact that, for a given foreign output, Home always has higher Welfare under non-strategic Emission Standards than under the same Design Standard and that Welfare under either standard is declining in foreign output.

First we show that the non-strategic Nash Equilibrium targets under Emission Standards are lower than under Design Standards. This is done by contradiction.

i) We know that output under any Emission target, output (q^E) couldn't exceed output under a Design Standard since marginal costs, in both countries, are never lower than those under Design Standards. Hence any equilibrium output must be lower. If targets are very lax, then firms are effectively unregulated. This generates the same output as Design Standards.
ii) An optimally chosen Design Standard sets marginal abatement costs ($D'(q^D,E)$) equal to marginal damages $G'(E)$. Call this target EOS^{DD}.
iii) Similarly, for an optimally chosen non-strategic Emission Standard. Call this EOS^{EE}. Recall that if strategic effects are taken into account, the regulator will choose its target such that $D'(q^D,E)$ is less than $G'(E)$ in equilibrium.
iv) Now suppose that, in equilibrium, each nation chooses a Emission target so that $EOS^{EE} > EOS^{DD}$.
v) This means that $G'(EOS^{EE}) \geq G'(EOS^{DD})$ since marginal damages are non-decreasing in emissions.
vi) Hence we must have $D'(q^E,EOS^{EE}) \geq D'(q^D,EOS^{DD})$ for this to hold..
vii) But marginal abatement costs fall as the stringency of targets falls (EOS rises) and when output falls so (vi) must be false. That is, it cannot be the case that choosing a weaker, non-strategic, Emission target raises marginal abatement costs in equilibrium. Hence (iv) cannot hold and we must have $EOS^{EE} \leq EOS^{DD}$.

Now consider Home's problem of choosing regimes given Foreign's output is fixed. Define W^E and W^D as Home's welfare under the two regimes.

i) First, for a given target, Emission Standards yield higher profits than Design Standards since the firm's Design constraints satisfy the Emission constraint as well. Hence the firm (and country) always does as well under Emission Standards for a given target. In particular, we have: $W^E(E^D,q_f) \geq W^D(E^D,q_f)$ where E^D is the EOS under joint Design Standards.
ii) The regulator, however, can choose a different target that necessarily improves welfare above that of matching the Design target E^D. This yields: $W^E(E^E,q_f) \geq W^E(E^D,q_f) \geq W^D(E^D,q_f)$ where E^P is chosen under Emission Standards. Hence an optimally chosen Emission Standard dominates an optimally chosen Design Standard for a given Foreign output..

We now show that Home welfare, for either standard, is declining in foreign output.

i) Fix q_f and maximize home welfare.
ii) This yields either $W^D(q_f)$ or $W^E(q_f)$ depending on the regime.
iii) Now lower q_f. If the regulator maintains the same targets, the firm cannot do worse and, in general, will do better given the larger (residual) demand for its product.

iv) Hence welfare cannot fall in either regime if foreign output falls. Conversely, if Foreign output rises, Home Welfare falls.

Now consider equilibrium welfare under each regime. Denote the values E^E and E^D as the (symmetric) equilibrium targets under the Emission and Design standards when both use the same regime. Denote $q^E{}_f$ and $q^D{}_f$ as Foreign's equilibrium outputs under the two respective regimes.

By the above we must have $W^E(E^E,q^E{}_f) \geq W^E(E^D,q^E{}_f) \geq W^D(E^D,q^E{}_f) \geq W^D(E^D,q^D{}_f)$.

Hence we have $W^E(E^E,q^E{}_f) \geq W^D(E^D,q^D{}_f)$.

Proposition 3.7: *If the Nash Equilibrium in strategic Emission targets yields a race to the bottom, then Design standards yield higher welfare. Design Standards are a weakly dominant strategy in this situation.*

This proof relies on the fact that output, under Design Standards, is the same as unregulated markets.

1. First we show that, if the Foreign firm is unregulated, Home prefers binding Design Standards to an unregulated Home firm.
   i) Denote slack Emission Standards as $E^S \geq e(q, 0)$. (I.e., the firm's emissions, even without any abatement activity is less than it is permitted to emit.)
   ii) With Foreign unregulated, equilibrium output is the same in Home under Design Standards (whether binding or not) and slack Emission Standards since the marginal cost schedule is unaffected by Design Standards.
   iii) Hence the rents Home extracts are the same under the two choices. Profits, however, will be lower if the Design Standard is binding ($A > 0$).
   iv) However, binding Design Standards reduce pollution so offer a potential benefit over unregulated markets.
   v) (iii) and (iv) imply that $W^D(A^D \geq 0) \geq W^D(A=0) = W^E(E^S)$ where A^D is the optimal Design Standard given Foreign is unregulated and E^S is a slack Emission Standard.

2. Now we look at Home's choices when Foreign uses Design Standards.
   i) We note that the payoff choices for Home are unchanged since Foreign's marginal cost schedule is the same as if regulated with slack Emission Standards.
   ii) So, if Home's optimal Emission Standard was slack when Foreign had slack Emission Standards, then it will also be slack when Foreign uses Design Standards.
   iii) By (1v) and (2i) we must have $W^D(A^D \geq 0) \geq W^D(A=0) = W^E(E^S)$ as before.

3. Hence Home's payoffs are identical regardless of Foreign's choice of regime. Therefore Design Standards are a weakly dominant strategy.

APPENDIX III: DATA DESCRIPTION

The following describes the data used in regressions, their sources, and construction. Two independent data sets were used. The primary data set is for the 22 OECD countries used in the paper. The second set was for all countries of the world and is used to calculate ALTw.

A3.1: Shipment Data:

Shipment data comes from the OECD Compatible Trade and Production (COMTAP) database that is available from the NBER on their "Trade Database Disc 2: World Trade Flows 1970-1992" CD-ROM. Refer to NBER working paper 5910 for a more thorough description of the data used. There is data on 22 OECD countries: Australia, Austria, Belgium-Luxembourg, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Turkey, United Kingdom, United States, and Yugoslavia. Data covers the period 1970 to 1985. Trade data is restricted to ISIC3 manufacturing trade.

Total ISIC3 imports and exports to the world were reported. With a full matrix of bilateral trades, it is possible to find exports from x to m using m's import data. Total exports can be calculated by summing across all m countries. Unfortunately, this data set does not contain all import data since it reports only imports of the 22 countries. It is NOT possible, therefore, to calculate total exports from a country by using their trading partner's import data. This is the preferred approach since import data is often more accurate.

Also available on the disc is Statistics Canada's World Trade Database that gives bilateral trade for all merchandise trade for all the countries in the world from 1970 to 1992. Trade is reported at the 6-digit Standard International Trade Classification (SITC) level as well as at the aggregate level. Aggregate trade replicating the countries in the COMTAP data set were extracted for comparison purposes.

Shipment data, originally reported using the Standard International Trade Classification (SITC), was converted to the ISIC categories for a concordance with production data. Both exports to and imports from all countries in the world are reported for all 22 countries. All values are reported in thousands of US$.

Production data is provided at the four-digit International Standard Industrial Classification (ISIC), Revision 2 for thirteen of the countries and at the three digit level for the remaining countries. Only manufacturing goods, starting with ISIC code 3, are included. I used only the three digit level.

Internal shipments were calculated as the difference between total production and total exports for that particular ISIC category. For some countries, notably Netherlands and Belgium, internal shipments were negative for some of the 3-digit categories indicating exports exceeded production. This probably occurred since entrepot trade (re-exports) is not accounted for in the shipments data and so will raise measured exports above their true levels. This also occurred for a few of the 2-digit categories but not at the one-digit aggregate level.

A3.2 Ancillary Data:

GDPx,GDPm: Gross Domestic Product in millions of US$ adjusted for Purchasing Power Parity (PPP) for the exporting or importing country. Each country has GDP adjusted values for 1970 to 1985 except for Yugoslavia which has unadjusted GDP since no PPP values are available. Belgium and Luxembourg are aggregated together. Data is collected from "Trends in International Distribution of Gross World Product", United Nations, 1993.

PPP adjusted GDP for countries in the rest of the world is taken from either the UN's World Development Indicators (WDI) disc or the PENN World Tables. The WDI disc has GDP and PPP data for 1980-95 for up to 130 countries. The PENN tables have PPP data for about 118 countries for 1970-92. The two data sets were merged using WDI data for post 1980. Some countries had incomplete PPP data. These were completed by extending existing PPP adjusted GDP using yearly differences in inflation rates between the country and the US. The WDI disc has this data for most countries for 1970-95. Some countries had no PPP data at all. OLS regressions of GDP at PPP values against GDP in local currency units, exchange rates in US$, and Population were run for those countries with the available data. Regression coefficients were then used to convert GDP in local currency to PPP adjusted GDP.

POPx, POPm: Population in thousands. Taken from PENN World Tables Version 5.6 for the 22 countries in the study. Population figures for the rest of the world come from the WDI disc.

DISTxm: Bilateral distance between economic centers of exporting and importing nation. Measured in kilometers using the Great Circle distance. Economic center of a country is generally taken as its Capital city with one exception. Chicago is taken as the economic center of the United States. Locations are the same as in Helliwell, 1998 and Wei (1996). Internal distances (x equal m) are generally calculated as one quarter of the distance to the nearest trading partner. Adjustments are made for island states (Japan, New Zealand, and Australia). This is the same procedure used by Wei. (1996) and Helliwell (1998). Latitudes and Longitudes are taken from "Direct Line Distances: International Edition", by Gary L. Fitzpatrick and Marilyn J Modlin, 1986, Scarecrow Press, London. See Table 3 for latitude and longitudes as well as internal distances. Internal distances using Nitsch's method were calculated as 0.2 $\sqrt{(\text{area in km}^2)}$. Land area was taken from Microsoft's Encarta disc 1998.

ALTx: Alternative market access. Measured as the sum of all x's trading partner's GDP divided by bilateral distances but not including partner m. $ALT_{xm} = \sum_j [GDP_j/DIST_{xj}]$, j not equal to m or x. Only the 22 countries in the sample are included. This can also be calculated as:

$$\begin{aligned} ALT_{xm} &= (\textstyle\sum_j [GDP_j/DIST_{xj}], \text{ j not equal to x}) - GDP_m/DIST_{xm} \\ &= ALT_x - GDP_m/DIST_{xm}. \end{aligned}$$

$ALTw_{xm}$: Alternative market access using all country data. Calculated the same as ALT_{xm} but including 161 countries

$ALTh_{xm}$:. Alternative market access including home market. Measured as the sum of all x's trading partner's GDP divided by bilateral distances but not including partner m. $ALTh_{xm} = \sum_j [GDP_j/DIST_{xj}]$, j not equal to m. Note that GDP_{xx} is included where $DIST_{xx}$ is taken as internal distance using Helliwell's method. Only the 22 countries in the sample are included

Tariff and non-tariff barriers are reported for 10 importing countries for the 3-digit ISIC manufacturing sectors in 1983 only. The importing countries are Belgium, Finland, France, Italy, Germany, Japan, Netherlands, Norway, United Kingdom, and the United States. Exporting countries are the above with Australia, Canada, and Sweden added. Four types of barriers are used: price, quantity, threat, average tariffs. The first three are coverage ratios that give the percentage of imports covered by one or more NTB. The coverage ratios are weighted averages of the indicator variable (one or zero) for that type of NTB using import values as weights. There is also an average NTB. This data set was constructed and used by Harrigan (1993).

A3.3: Dummy Variables:

European Union membership: For the beginning of the sample period 1970 there were five members in the European Community: Belgium-Luxembourg, France, Germany, Italy, and the Netherlands. Trade between these countries is given the dummy variable EU70. In 1973, Denmark, Ireland, and the United Kingdom joined the EC. Trade between these three countries and with the existing EC countries is given the dummy variable EU73. Greece joined in 1981. EU81 refers to trade between Greece and the existing 8 members of the EU. These non-accumulating EU dummies allow for differences in the internal trade densities depending on the length of membership

Common languages: This is dummy that takes on a value of one if both importer and exporter share a common language. Common languages are listed below.

English	Australia, Canada, Ireland, New Zealand, United Kingdom, United States
French	Belgium, Canada, France,
German	Austria, Germany
Dutch	Belgium, Netherlands

Ocean Access: This is a dummy that takes on a value of one if both importer and exporter share access to deepwater ports. Austria is the only country of the 22 that is landlocked. This dummy excludes trade where shipments can be expected to use a different mode of transport than deepwater shipping. For example, Canada and the US both have deepwater ports but most trade is over land so the dummy takes a value of zero. This is also true for Denmark and Sweden, Germany and France, etc. Internal trade is also excluded. The following table indicates which partners DO NOT share deep ocean trade.

AUS	AUT
AUT	All countries
BEL	AUT FRA GER NET
CAN	AUT USA
DEN	AUT FIN GER NOR SWE
FIN	AUT DEN NOR SWE
FRA	AUT BEL GER ITA NET SPN
GER	AUT BEL DEN FRA NET
GRC	AUT TUR ITA YUG
IRE	AUT UKG
ITA	AUT FRA GRC
JPN	AUT
NET	AUT BEL FRA GER
NOR	AUT DEN FIN SWE
NZL	AUT
POR	AUT SPN
SPN	AUT FRA POR
SWE	AUT DEN FIN NOR
TUR	AUT GRC YUG
UKG	AUT IRE
USA	AUT CAN
YUG	AUT GRC ITA TUR

Adjacency: This is a dummy that takes on a value of one if both importer and exporter share a common land border.

Own trade. This is a dummy that takes on a value of one if exports are internal. Note that the dummies for adjacency, ocean access, common language, and EU participation are all zero when own trade is one.