TRADE, GROWTH AND THE ENVIRONMENT
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1. Introduction

For the last ten years environmentalists and the trade policy community have engaged in an often times fruitless debate over the environmental consequences of liberalized trade. The debate was originally fueled by negotiations over the North American Free Trade Agreement and the Uruguay round of GATT negotiations, both of which occurred at a time when concerns over global warming, species extinction and industrial pollution were rising. Recently it has been intensified by the creation of the World Trade Organization (WTO) and proposals for future rounds of trade negotiations.

The debate has often been fruitless because the parties differ greatly in their trust of market forces and typically value the environment differently. The debate has also been hampered by the lack of a common language and suffered from little recourse to economic theory and empirical evidence. This is perhaps not surprising because the theoretical relationships between international trade and the environment are not well understood, and the empirical literature linking the two is both small and variable in quality.

The purpose of this essay is set out what we currently know about the environmental consequences of economic growth and international trade. We critically review both theory and empirical work to answer three basic questions. What do we know about the relationship between international trade, economic growth and the environment? How can this evidence help us evaluate ongoing policy debates in this area? Where do we go from here?

To answer these questions, we discuss both the empirical and theoretical literature with the aid of a relatively simple general equilibrium model where government policy and private sector behavior interact to determine the equilibrium level of pollution. The model is developed in Section 2 of the paper and then employed in various guises throughout. Our use of a model to organize our review reflects the overall theme of our essay: economic theory needs to play a
much larger role in guiding empirical investigation, suggesting alternative hypotheses, and disciplining inferences. As we show, the vast majority of empirical work in this field is devoid of explicit theory, and this has sometimes led it astray.

The economic literature on these issues came in two waves, with an initial surge of activity in the 1970's\(^1\) and a resurgence of interest stimulated by the policy debates of the past decade. Much of the earlier literature was normative, with a focus on issues such as gains from trade and optimal trade or environmental policies.\(^2\) A large component of recent work also focuses on second best policy analysis. However, a significant feature of the recent literature is its concern with positive issues: generating and attempting to test hypotheses about how trade or growth affect environmental outcomes. We view these latter issues as fundamental to resolving the current policy debates, and so most of our essay will focus on this aspect of the literature.\(^3\)

Therefore after developing our model in Section 2, we start our investigation in Section 3 by examining the link between incomes per capita and environmental quality. Interest in this link arose from the pioneering work by Grossman and Krueger (1993) on NAFTA and has subsequently led to a burgeoning literature on what has come to be known as the Environmental Kuznets Curve (EKC). This literature is important because many in the trade policy community have argued that trade and growth may actually be good for the environment. If environmental quality is a normal good, increases in income brought about by trade or growth will both increase the demand for environmental quality and increase the ability of governments to afford costly investments in environmental protection. Not surprisingly then, a common view within the trade policy community is that trade doesn't cause environmental problems; bad environmental policy cause environmental problems.

While this may in fact be correct, it is important to establish what the finding of an EKC does and does not imply about the likely environmental implications of international trade. To this end, we employ our simple general equilibrium model to illustrate two points relevant to this

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\(^1\) See, for example, Baumol (1971), Walter (1973), Markusen (1975), Pethig (1976), and Siebert (1977).

\(^2\) Exceptions include Walter's (1973) empirical paper and Pethig (1976) on the pattern of trade.

\(^3\) Other recent surveys that focus more on policy include Rauscher (2001) and Ulph (1997). Nordström and Vaughan (1999) provide a good comprehensive review of the trade and environment literature.
aspect of the trade and environment debate. The first is a theoretical point. We show how a EKC relationship can arise in many situations: in fact we demonstrate that a tightening of pollution policy in response to income gains is neither necessary nor sufficient for an EKC relationship to obtain. Therefore, observing an EKC relationship in the data may or may not indicate a strong policy response tied to income gains. And evidence of an EKC is not evidence that income gains brought about by freer trade will improve environmental quality.

Our second point relates to empirical work. To illustrate the many alternative explanations for the EKC finding we start with our simple general equilibrium model and then place restrictions on tastes, technology or the number of goods to generate the EKC result. Without these restrictions, the model provides a simple pollution demand and supply system linking pollution levels to national characteristics (incomes, factor endowments and technologies) and trading opportunities (comparative advantage and current trade restrictions). Theories of the EKC, reduce this set of possible explanatory factors to essentially just one – incomes per capita. As a consequence of our construction, the reader is led to question why we might want to impose these restrictions on empirical estimation ex ante. Stepping back from the literature and adopting the theoretical perspective offered by our simple general equilibrium model, it is hard to see why future empirical investigations between environmental outcomes and aggregate economic characteristics should proceed along EKC lines.

While the link between trade, growth and the environment is an important one, environmentalists are however concerned that trade may exacerbate environmental problems through a variety of channels. While trade may stimulate economic growth and then indirectly lead to more pollution, it may also encourage a relocation of polluting industries from countries with strict environmental policy to those with less stringent policy. These shifts may in turn increase global pollution. Moreover freer trade could also have a chilling effect on environmental policy, as countries will be reluctant to tighten environmental regulations because of concerns over international competitiveness. Economists have typically countered these claims by noting the empirical evidence for pollution havens is weak with the relevant empirical literature failing to find a strong relationship between differences in environmental regulations across countries.
and trade or investment flows. Consequently, concerns over dirty industry migration, pollution havens, and regulatory chill, are overblown.

To examine this part of the debate we must consider the impact of international trade itself and investigate the determinants of trade patterns in pollution intensive goods. To do so we proceed in section 4 to examine the implications of international trade holding constant all other determinants of income growth. We demonstrate how the impact of trade liberalization on the environment depends on a country's comparative advantage; how this dependence is affected by the choice of policy instrument; and how this dependence is reliant on income effects. In doing so we demonstrate how and when the pollution haven hypothesis may hold, and introduce alternative explanations for trade in pollution intensive goods as well.

With these theoretical results in hand, we then review empirical studies linking international trade and environmental outcomes. In reviewing the literature we focus on the three challenges facing empirical research in this area. These are: (1) data availability; (2) the absence of direct measures of environmental stringency; and (3) the endogeneity of regulation. Various studies have attacked or ignored these problems in different manners. Our review introduces the reader to each of the different methods employed in the literature and discusses their strengths and weaknesses. In total, the review suggests that the empirical evidence is still far from clear.

Our review of this literature contains two main messages. The first is that the literature’s focus on pollution havens and its attention to national income differences has led it to severely underestimate the role played by more conventional determinants of comparative advantage. Natural resource abundance and capital abundance appear to be far better predictors of dirty good production and trade than is a low-income level. The second message is that the endogeneity of pollution policy needs to be taken seriously in empirical work. Failure to do so has led the empirical literature to prematurely conclude that differences in regulation don’t matter.

Finally with the theory and empirical work reviewed, in Section 5 we turn to examine two key policy questions. Should trade policy be used to achieve environmental objectives? Should environmental policy be constrained by international trade law to prevent countries from using it as a substitute for trade policy? By relying on our theoretical framework and our review of the available evidence we argue against the use of trade policy for environmental objectives.
We also argue, that at present, it is premature to develop any explicit links between trade and environmental policy.

A short conclusion sums up.

2. The Model

We start by developing a very simple model to use as a vehicle for discussing the interaction between international trade and the environment.\(^4\) We have opted for simplicity rather than generality; and do not attempt to be fully exhaustive in our coverage. Our objective is to provide a clear and simple expository framework to help interpret the literature.

We adopt a static model and focus on production-generated pollution.\(^5\) Pollution from a given firm harms consumers but does not affect the productivity of other producers.\(^6\) There are two goods, \(X\) and \(Y\), each produced with a constant returns to scale technology using two primary factors, capital \((K)\) and labor \((L)\). To capture differences in pollution intensity across sectors, we assume that \(X\) generates pollution during production, but that \(Y\) does not pollute at all.

The production function for good \(Y\) is simply:

\[
Y = H(K^y, L^y). \tag{2.1}
\]

where \(H\) is increasing, concave and linearly homogeneous.

The \(X\) industry jointly produces two outputs – good \(X\) and emissions \((Z)\). However, abatement is possible, and so emission intensity is a choice variable. To capture the possibility of abatement very simply, assume that a firm can allocate an endogenous fraction \(\theta\) of its inputs to abatement activity. Increases in \(\theta\) reduce pollution, but at the cost of diverting primary factors from \(X\) production. The joint production technology is given by:

\[
x = (1-\theta)F(K^x, L^x), \tag{2.2}
\]

\(^4\) The model is based on Antweiler, Copeland and Taylor (2001), which has its roots in Copeland and Taylor (1994). See also McGuire (1982) and Rauscher (1997).

\(^5\) Models with consumption-generated pollution have been somewhat neglected in the trade literature. For one example, see parts of Copeland and Taylor (1995b) and Rauscher (1997).

\(^6\) Production externalities are discussed in Copeland and Taylor (1999) and Bennaroch and Thille (2001).
\[ z = \phi(\theta) F(K_x, L_x), \]  

(2.3)

where \( F \) is increasing, concave and linearly homogeneous, \( 0 \leq \theta \leq 1, \phi(0) = 1, \phi(1) = 0, \) and \( d\phi/d\theta < 0. \) We can think of \( F(K_x, L_x) \) as potential output; this is the output of \( X \) that would be generated if there were no pollution abatement. If \( \theta = 0, \) there is no abatement effort, and each unit of output generates one unit of pollution. As \( \theta \) rises, resources are shifted towards abatement, lowering both final \( X \) production and pollution.

While pollution is a joint output, much of the literature treats pollution (or environmental services) as an input for analytical convenience. To do so, one can invert (2.3) to solve for \( \theta, \) and substitute into (2.2) to obtain output of \( X \) as a function of emissions and primary inputs. It is convenient for expository purposes to put a little more structure on (2.3) before doing this; hence we adopt the following functional form for abatement:

\[ \phi(\theta) = (1 - \theta)^{1/\alpha} \]  

(2.4)

where \( 0 < \alpha < 1. \) Using (2.4), we can eliminate \( \theta \) and invert the technology to obtain:

\[ x = z^{\alpha}[F(K_x, L_x)]^{1-\alpha}, \]  

(2.5)

which is valid for \( z \leq F, \) because \( \theta \leq 1. \) We can think of \( X \) as being produced from capital, labor, and environmental services. This allows us to make use of familiar tools, such as isoquants and unit cost functions.

Figure 1 illustrates a typical isoquant. At point A, no abatement is undertaken, and pollution is proportional to output (we have chosen units so that the factor of proportionality is one). As we move down the isoquant, the firm both reduces pollution and maintains output constant by using more primary factors and allocating some of them to abatement activity.

We denote the price of \( X \) by \( p, \) and treat \( Y \) as the numeraire. If there is no pollution regulation, firms face a zero price for emissions and do not undertake any abatement. If governments do regulate pollution, we assume that firms face a price \( \tau \) for each unit of emissions that they release. This price may be implemented with either a pollution emissions tax \( \tau \) or by a tradable emissions permit system, in which the government sets the total level of pollution \( Z, \) and the emissions price \( \tau \) is determined in the market.
Cost minimization in the X industry

Figure 1

Cost minimization in the X industry
Firms choose the emissions intensity that minimizes their production costs. Let \( c^F(w, r) \) be the minimum cost of producing a unit of the aggregate primary input bundle \( F \), where \( w \) and \( r \) denote the returns to labour and capital. Then the cost of producing \( X \) is \( c^F + \tau z \), which yields the isocost line in the figure. At an interior solution (point B), firms equate the slopes of the isocost line and the isoquant. Solving this problem determines emissions per unit of output, which we denote by \( e \):

\[
e \equiv \frac{z}{x} = \frac{\alpha p}{\tau} \leq 1
\]  

The emission intensity falls as pollution taxes rise; and it rises when the price of the polluting good \( p \) rises because the opportunity cost of resources used in \( F \) is higher.

To close the production side of the model, we require non-positive profits in each industry, and full employment. These conditions can be solved to obtain outputs as functions of endowments, prices and policy:

\[
x = x(p, \tau, K, L) \\
y = y(p, \tau, K, L)
\]

For a given pollution tax, it can be verified that this model behaves much like the standard Heckscher-Ohlin model of international trade. In particular, an increase in the supply of capital will increase the output of the capital-intensive industry \( X \), and reduce the output of \( Y \); and an increase in the supply of labor stimulates \( Y \) and contracts \( X \).

We can summarize the production side of the model with a national income function. Because markets are competitive, the private sector maximizes the value of national income, for any given any pollution level \( Z \). This allows us to write national income \( G \) as the solution to an optimization problem:

\[
G(p, K, L, Z) = \max_{\{x, y\}} \{ px + y: (x, y) \in T(K, L, Z) \}
\]

\footnote{If the pollution tax is sufficiently low, firms will not abate at all, and a corner solution at point A in the figure will result. At this point \( z = x \), and so \( e = 1 \). Referring to (2.6) this no-abatement solution occurs if \( \tau \leq \tau = \alpha p \).}

\footnote{The tangency condition is \( c^F/\tau = (1-\alpha)z/F\alpha \). Linear homogeneity of the production function implies \( px = c^F + \tau z \). Combining yields the result. Alternatively, note that the Cobb-Douglas form of the production function implies that the share of emission charges in the value of output is \( \alpha = \tau z/px = \tau e/p \).}
where $T$ is the feasible technology set. As is well known, the national income function satisfies a number of useful properties. Most useful to us is the following:

$$
\tau = \frac{\partial G}{\partial Z}.
$$

(2.9)

The equilibrium price of a pollution permit is equal to the effect on national income of an increase in allowable pollution; that is, if more pollution is allowed, national income rises by the value of the marginal product of emissions. If we instead think of the effects of a reduction in emissions $Z$, then the cost to the economy is also given by $\partial G/\partial Z$. This is the general equilibrium marginal abatement cost. Hence another interpretation of (2.9) is that the price of a unit of emissions is equal to the marginal abatement cost; which is a standard result in environmental economics.

**Consumers**

We assume there are $N$ identical consumers in the economy. Each consumer maximizes utility, treating pollution as given. For simplicity, we assume preferences over consumption goods are homothetic and the utility function is strongly separable with respect to consumption goods and environmental quality. The indirect utility function for a typical consumer is then given by

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9 It is concave in $(K, L$ and $Z)$ and convex in prices. Moreover, outputs and factor prices can be recovered with simple differentiation: $x = \partial G/\partial \xi$; $r = \partial G/K$; $w = \partial G/L$. The first result follows from the envelope theorem: if the price of $x$ rises by a dollar, then to a first order, the value of national income rises by the amount of the initial output of $X$. The next two results can be interpreted by noting that an increase in the supply of a factor raises national income by the value of its marginal product, which is the factor price in a competitive economy. See Woodland (1982) and Dixit and Norman (1980) for the standard treatment of national income functions, and Copeland (1994) for an application to environmental problems.

10 Homotheticity allows us to write the indirect utility function as an increasing function of real income (nominal income divided by a price index). This simplifies our problem considerably. Homotheticity also ensures that the relative demand for goods is unaffected by income levels. This is a standard assumption in the international trade literature and it allows us to focus on the role of environmental policy and factor supplies in explaining trade patterns. Strong separability means that the marginal rate of substitution between $X$ and $Y$ is not affected by the level of environmental quality and it also limits the extent to which goods prices can affect the demand for environmental quality.
\[ V(p,I,z) = v(I / \bar{p}(p)) - h(z) \]  

(2.10)

where \( h \) is increasing and convex, \( I \) is per capita income (so \( I = G/N \)), \( \bar{p} \) is a price index, and \( v \) is increasing and concave. Pollution is harmful to consumers and is treated as a pure public bad (all consumers experience the same level of pollution).

2.1 The Demand for Pollution

In our approach, we treat pollution as if it was an endogenously supplied factor of production. This suggests a natural way to think about the determinants of pollution is in terms of its demand and supply.

Notice (2.9) can be interpreted as the inverse demand for pollution. We illustrate this demand curve in Figure 2. It slopes down because \( G \) is concave in \( z \). More intuitively, we can exploit the structure we imposed on technology to write pollution demand as

\[ z = e(p/\tau)x(p,\tau,K,L) \]  

(2.11)

This is the same relation we would obtain by inverting (2.9) and using our assumptions on technology. From (2.11), we can see that the demand for pollution slopes down for two reasons: as \( \tau \) falls, firms pollute more both because the emissions intensity \( e \) rises, and because the lower tax on pollution makes production of the dirty good more attractive (so that output of \( X \) expands while \( Y \) contracts).

2.2 The Supply of Pollution

Pollution supply depends on the policy regime. If there is no regulation, then pollution supply is perfectly elastic at \( \tau = 0 \). Pollution in this case is entirely demand driven. If there is an exogenous pollution tax \( \tau_0 \), then supply is a horizontal line. Shifts up or down in pollution demand raise or lower emissions. Alternatively, if there is a fixed overall pollution quota in place
(as in a tradable emission permit system), then the pollution supply curve is vertical. Shifts in pollution demand raise or lower the price of emissions, but have no effect on overall pollution.

In general, we expect pollution policy to be endogenous; and in particular, we expect that changes in per capita income will lead to an increase in the demand for environmental quality, and (if governments are responsive) a tightening up of pollution regulations. The endogeneity of the pollution policy regime plays a key role in both the theory and empirical literature.

There are two approaches to modeling the policy process. One is to simply assume a benevolent government chooses policy. Another is to adopt a political economy framework where the interaction of competing interest groups determines policy.\textsuperscript{11} We follow the bulk of the literature on endogenous policy and adopt a representative agent framework in which the government provides efficient policy.\textsuperscript{12}

To determine the optimal pollution policy, the government chooses the pollution level to maximize the utility of a representative consumer subject to production possibilities and private sector behavior. That is, the government's problem is:

$$\begin{align*}
\text{Max}_z \{V(I / \beta(p), z) & \quad \text{s.t.} \quad I = G(p, K, L, z) / N \} \\
\end{align*}$$

(2.12)

Because we assume that the economy is small in world markets, the government treats the goods price $p$ as given and unaffected by policy. Hence $dp/dz = 0$ and the first order condition from (2.12) becomes:

$$\frac{VG_z}{N} + V_z = 0.$$  

To simplify, recall that $G_z = \tau$, which is the private sector's marginal valuation for a unit of pollution. As well, define $R = I/\beta(p)$ as real income of the representative consumer. We can then rewrite the first order condition as:

$$\tau = N \cdot [-V_z / V_I] = N \cdot MD(p, R, z)$$

(2.13)

\textsuperscript{11} The use of political economy models in the trade and environment literature is still in the early stages. Examples include Hillman and Ursprung (1994), Fredriksson (1997, 1999), Gulati (2001), Raucher (1997; ch. 5) and Schleich (1999).

\textsuperscript{12} See however our discussion of political economy elements in section 5 on policy implications.
where $\text{MD}(p, R, z)$ is a representative consumer's marginal damage from pollution (the marginal rate of substitution between pollution and income). The optimal tax simply implements the standard Samuelson rule: the pollution tax is the sum of marginal damages across all individuals.

If pollution policy is implemented efficiently, then (2.13) can be interpreted as the supply of pollution. As shown in Figure 2, the supply curve slopes upwards because increases in pollution tend to make environmental quality scarce relative to consumption. That is, a diminishing marginal rate of substitution between consumption and environmental quality yields an upward sloping supply curve. As well, exogenous increases in endowments or technology that increase real income will shift the supply curve in: because environmental quality is a normal good, marginal damage is increasing in real income ($\text{MD}_R > 0$).

2.3 Market equilibrium with efficient policy

The equilibrium level of pollution is determined by the interaction between the derived demand for pollution and the aggregate marginal damage as captured in pollution supply. Combining (2.9) and (2.13) yields:

$$G_z(p, K, L, z) = N \cdot \text{MD}(p, R(p, K, L, z), z).$$  \hfill (2.14)

Equation (2.14) determines the efficient level of pollution $z^o$, as illustrated in Figure 2. To implement $z^o$, the government can either introduce a pollution tax $\tau^o$, or issue $z^o$ marketable permits which would yield an equilibrium permit price $\tau^o$.

2.4 Scale, Technique and Composition Effects

It is very useful to have a simple way to decompose and identify how changes in the economy affect environmental outcomes. Such a decomposition is critical for empirical work because we have to distinguish between the effects of growth, trade, and other factors if we are to

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13 $R$ also varies endogenously with $z$; this is taken into account when drawing the supply curve.
Figure 2
Pollution Demand and Supply
measure their importance. Grossman and Krueger (1993) in their study of NAFTA used the concepts of scale, composition and technique effects as the basis of their discussion, and we proposed formal model-based definitions in Copeland and Taylor (1994). Here we employ the definitions to provide a simple decomposition.

**Definitions**

Trade and growth both increase real income, and therefore both increase the economy’s scale. To be more precise, we need a measure of the scale of the economy; that is, we need an index of output. There many ways to create such a quantity index, but for simplicity, we will use the value of gross or potential output (including resources allocated to abatement) at a given level of world prices as our measure of the economy’s scale. That is, our measure of scale, $S$, is defined as

$$S = p_x^0 F + p_y^0 y$$

(2.15)

where $p_x^0$ and $p_y^0$ denote the base-period level of world prices; that is, the level of world prices prior to any shocks that we analyze. Recall that $F = x + \theta F$, where $\theta F$ is the potential output of $X$ that is lost by diverting resources to abatement; hence $p_x^0 F$ is a measure of the potential output of the economy measured at base prices, including resources used in abatement. If world prices change, we continue to construct $S$ using the old (initial) world prices. This is so that scale will not change simply because of a change in valuation.

Given this definition of scale, and setting base-period prices to unity, we now use (2.15) to write pollution as

$$z = ex = e\varphi_x S$$

(2.16)

where $\varphi_x = p_x^0 x / S = x / S$ is the value share of $x$ in total output evaluated at base-period prices. Hence pollution emissions depend on the emissions intensity of production, $e$, the importance of the dirty good industry in the economy, $\varphi$, and the scale of the economy, $S$.

Taking logs and totally differentiating yields our decomposition of changes in pollution into three components:
\[
\hat{z} = S + e + \phi
\]  
(2.17)

where \(z = \frac{dz}{dz}\), etc.

The first term is the **scale effect**. It measures the increase in pollution that would be generated if the economy were simply scaled up, holding constant the mix of goods produced and production techniques. As an example, if there were constant returns to scale and all of the endowments of the economy grew by 10%, and if there were no change in relative prices or emissions intensities, then we should expect to see a 10% increase in pollution.

The second term is the **composition effect** as captured by the change in the share of the dirty good in national income. If we hold the scale of the economy and emissions intensities constant, then an economy that devotes more of its resources to producing the polluting good will pollute more.

Finally, we have the **technique effect**, captured by the last term in (2.17). Holding all else constant, a reduction in the emissions intensity will reduce pollution.

Let us illustrate these concepts with an example. Suppose there is capital accumulation, and for simplicity, suppose the policymakers hold the emission intensity fixed. In the top half of Figure 3 we have sketched the gross production frontier; and in the bottom half, we determine pollution \(Z\). To determine the equilibrium production point on the frontier, note that profits in the X sector are given by

\[
\pi^x = p_x - wL_x - rK_x - \tau Z
\]  
(2.18)

But using (2.16) and \(z = e^x\), we can determine a relation between \(x\) and potential output \(F\):

\[
x = e^{\alpha/(1-\alpha)} F(K_x L_x)
\]  
(2.19)

Using (2.19) and (2.6), we can rewrite (2.18) as:

\[
\pi^x = p^NF(K_x L_x) - wL_x - rK_x
\]  
(2.20)

where \(p^N \equiv p(1-\alpha)e^{\alpha/(1-\alpha)}\) can be interpreted as the net price facing producers when pollution charges and abatement activity is internalized. Hence the initial production point in Figure 3 is at
point A, where the frontier has slope \(-p^N\). The scale of the economy at this point is measured by the line \(p_0\) through A which has slope equal to base prices. Pollution can be determined by using:

\[ z = ex = e^{1/(1-\alpha)} F(K_xL_x) \]  

(2.21)

This line is plotted in the bottom half of Figure 3 for the given level of \(e\). Pollution is initially \(Z_A\).

With capital accumulation, the production frontier shifts out, but the shift is biased towards F because F is capital intensive. With a fixed emission intensity, \(p^N\) does not change and so the new production point is at C, and the new level of pollution rises to \(Z_C\). Pollution rises because capital accumulation stimulates the capital-intensive sector, which is also pollution intensive in our model.

The increase in pollution can be decomposed into scale and composition effects (we ruled out a technique effect by assumption). Holding scale of the economy fixed, the increase in relative capital abundance creates a change in the composition of output given by the movement from A to B. This pure composition effect increases pollution from \(Z_A\) to \(Z_B\). Capital accumulation also increases the scale of output, captured in the figure by the movement from B to C. This scale effect raises pollution from \(Z_B\) to \(Z_C\).

3. The Environmental Kuznets curve

We now turn to substantive issues. We start with the literature on the relationship between income and the environment. This has been the subject of a rapidly expanding empirical literature, and a key aspect of the debate on trade and environment. The main argument for free trade is that it will raise national incomes; but if this is so, then it is important to understand how higher incomes affect environmental quality.

\[ \text{If the regulator tightens up pollution policy in response to capital accumulation, this would be captured in our diagram as follows. The increase in the pollution tax would reduce the producer price } p^N. \text{ This would dampen the composition effect. And as well, the pollution line in the bottom half of the figure would rotate up as } e \text{ falls. This technique effect would tend to reduce pollution. The net effect on pollution depends on the sum of all three effects. Pollution could actually fall if the technique effect is strong enough to offset the scale and composition effects.} \]
Figure 3

The Composition Effects
The empirical literature on the relationship between per capita income and pollution has come to be known as the Environmental Kuznets curve (EKC) literature. The Environmental Kuznets Curve (henceforth EKC) is an empirical relationship that links a specific measure of environmental quality to per capita income levels. The EKC relationship is often depicted graphically with pollution on the vertical axis and per capita income on the horizontal. The measure of per capita income is typically average per capita income in the region or country where the measurement was taken. Estimates of EKC from Grossman and Krueger (1993) or (1995) describe a hump-shaped curve for some pollutants: pollution at first rises and then falls with income per capita. For some others, pollution declines monotonically with income per capita; while for others (such as carbon emissions) pollution tends to rise with income per capita. The hump-shaped relation has captured the most attention, however. This literature has proliferated over the past few years - there are numerous papers that estimate an EKC for various pollutants, countries, time periods, etc.\textsuperscript{15}

What is perhaps most striking about the EKC literature is the limited role that theory has played in its development. This has created difficulties in interpreting the empirical results. For this reason, we will start off our review by asking what theory has to say about the relation between income and pollution before moving on to the empirical work.

The EKC literature seeks to estimate a relation between pollution and per capita income. Because the EKC is a relation between two endogenous variables, I and z, this will be problematic. From the vantage point of our demand and supply system, two difficulties immediately present themselves. The first is simply that since income and pollution are each a function of more primitive determinants, why should we expect to find a simple, stable relationship between them? It would be astonishing to find a simple stable relationship between all possible realizations of income and pollution. The second difficulty is that in many cases, income and pollution are determined simultaneously and hence the current practice of regressing one on the other is of some concern.

\textsuperscript{15} See Cavlovic et al (2000) and Ekins (1997) for recent surveys of this work.
To overcome the first difficulty, each of the explanations for the EKC implicitly puts strong restrictions on our pollution supply and demand system to generate the required result. A common type of restriction represents what we would call zero restrictions. These are restrictions imposed when assuming either pollution demand or supply is independent of certain factors. For example, assuming pollution demand shifts right with an increase in the scale of economic activity, but is independent of the composition of this activity, is a zero restriction because it says the composition of factor endowments is irrelevant to pollution demand. Similarly, separability assumptions can make pollution supply independent of relative prices and again this represents a zero restriction. These restrictions are typically employed to ensure that pollution levels are a function of income alone.

A second type of restriction involves assumptions on technology and preferences. These types of restrictions are imposed to generate the desired shape of the income-pollution relation. Therefore while theory suggests there may well be a stable relation between pollution and various primitives such as technology and primary factors of production, and between income and these same variables; there is little reason in general to expect that there will be a simple relation between pollution and income.\textsuperscript{16} All theories predicting an inverse-U shaped Environmental Kuznets Curve must proceed by imposing more structure than even our simple pollution demand and supply model contains.

There are four main explanations for the empirical finding of an EKC. We classify these explanations by the key mechanism driving their results. These are: (1) sources of growth; (2) income effects; (2) threshold effects; and (4) increasing returns to abatement. Although all of these explanations describe forces that could interact with each other, we will isolate the key features of each in our presentation.

\textsuperscript{16} Some empirical support for this view can be found in the work of Harbaugh et al (forthcoming). They examine the robustness of estimates of the environmental Kuznets curve for SO\textsubscript{2}. This was the focus of the original work of Grossman and Krueger (1993) and is one of the most widely cited examples of the existence of an environmental Kuznets curve. They find that the shape of the curve is very sensitive to changes in the time period chosen and the set of countries included in the study. This is highly suggestive of a misspecification of the model, which is exactly what the theory above suggests. A model that looks for a simple stable relation between income and pollution is unlikely to be correctly specified.
3.1 Sources of Growth

To establish that the relationship between pollution and income may differ when the sources of income growth differ, we compare physical and human capital accumulation. The source of growth explanation for the EKC is important to our discussion for two reasons. First, it demonstrates how the pollution consequences of growth depend on the source of growth. Therefore, the analogy drawn by some in the environmental community between the damaging effects of economic development and those of liberalized trade is, at best, incomplete. Second, the sources of growth explanation demonstrate that a strong policy response to income gains is not necessary for the EKC relationship. Hence the shape of the EKC need not be driven by income gains making pollution policy more stringent.

To illustrate how the sources of income growth matter it proves useful to assume no pollution regulation. In this case, the emission intensity is $e = 1$ and we can specialize (2.11) to write pollution as

$$z = x(p, \tau, K, L) \quad (3.1)$$

where $\tau = 0$ and income is

$$I = G(p, K, L, z) \quad (3.2)$$

Suppose growth occurs via capital accumulation alone. Then differentiating (3.1) and (3.2), holding $\tau = 0$ and $L$ constant, yields

$$\hat{z} = e_{xx} \hat{K} \quad (3.3)$$

and

$$\hat{I} = s_r \hat{K}. \quad (3.4)$$

where $e_{xx} > 0$ is the elasticity of $x$ output with respect to the endowment of capital, $s_r > 0$ is the share of capital in national income, and $\hat{z} = dz / z$, etc. That is, capital accumulation both raises income and raises pollution.
Combining (3.3) and (3.4) yields the reduced form relation between pollution and income:

\[ \hat{z} = \frac{e_x K_s}{s_r} \hat{I} \]  
\[(3.5)\]

With no pollution policy, there is a positive, monotonic relation between pollution and income if growth occurs via the factor used intensively in the dirty industry.

Alternatively, suppose growth occurs via accumulation of human capital. Then we have:

\[ \hat{z} = \frac{e_{xL}}{s_w} \hat{I} \]  
\[(3.6)\]

where \(e_{xL} < 0\) is the elasticity of \(x\) output with respect to the endowment of human capital and \(s_w > 0\) is the share of human capital in national income. Note \(e_{xL} < 0\), follows from the Rybczinski theorem of international trade: human capital accumulation stimulates the clean industry \(Y\), which draws resources out of the dirty industry \(X\) and lowers pollution. Hence when growth occurs via accumulation of the factor used intensively in the clean industry, there is a negative monotonic relation between pollution and income.

This simple example highlights how different sources of growth will in general trace out different relations between income and pollution. Unless all countries grow in exactly the same way, it is unlikely that a common environmental Kuznets curve will exist.

Although our major point here is to question the existence of a simple relation between income and pollution, it is useful to see what is needed to generate an EKC. To obtain the rising and then falling portions of an EKC, even in the absence of any environmental policy, we could place restrictions on the growth process across all countries. This yields one of the commonly mentioned explanations for the EKC, although it seems to lack a formal statement in the literature. Very simply, suppose policy is not very responsive to income (i.e. a restriction on pollution supply), but countries grow primarily via capital accumulation in the early stages of development and by human capital acquisition in later stages (i.e. restrictions on the time profile of demand shifters). Then pollution will rise and then fall with growth in per capita income as
composition effects driven by the factor growth drive the profile for pollution. Composition effects are key here, because we have assumed a zero policy response eliminating technique effects, and our model's composition effects always dominate scale effects. Given these assumptions, changes in the sources of growth are reflected in the pattern of pollution.

3.2 Income Effects

An alternative widely cited explanation for the EKC is that its shape reflects changes in the demand for environmental quality as income rises. If "the environment" is a normal good, pollution may at first rise with development but then fall when income levels continue to rise. To examine this theory, suppose governments set policy efficiently, and consider the effects of neutral progress. Neutral progress is assumed since this will neutralize the sources of growth explanation discussed above, leaving technique effects to carry the day. Let \( \lambda \) be a shift parameter representing technology, and again normalize the population so that \( N=1 \). With neutral technical change, we can write our GNP function as \( \lambda G(p,K,L,Z) \).

Pollution is determined by:

\[
\lambda G_z(p,K,L,z) = MD(p, \lambda G(p,K,L,z) / \beta(p),z)
\]  

and differentiating with respect to \( \lambda \) and rearranging yields:

\[
\frac{dz}{d\lambda} = \frac{1 - \varepsilon_{MD,R}}{\Delta}
\]  

where \( \Delta > 0 \), and \( \varepsilon_{MD,R} \) is the income elasticity of marginal damage. Neutral technological progress shifts both the demand and supply of pollution. Demand shifts because the marginal product of pollution rises creating a scale effect; supply shifts because real income has grown creating a technique effect. Whether pollution rises or falls with increases in real income only

\[17\] Lopez (1994) provides an early formal treatment of this approach, as he shows how non-homotheticity in preferences between consumption and environmental quality can lead to an EKC. Gawande et al (2001) provide an interesting variation on the income effect approach – in their model, agents are freely mobile and so income effects induce a sorting equilibrium in which higher income agents avoid polluted areas.
depends on the income elasticity of marginal damage from pollution.\textsuperscript{18}

If the elasticity is less than one, then the supply shift is swamped by the demand shift and pollution rises; if it is greater than one, just the opposite occurs. Because the EKC has both an increasing and decreasing segment, this pure income-driven explanation requires a variable income elasticity of marginal damage to generate the required shape.

To demonstrate this possibility, consider a standard constant absolute risk aversion subutility function for $v$, so that indirect utility is given by:

$$V(p, I, z) = c_1 - c_2 e^{-R/\xi} - h(z) \quad (3.9)$$

where $\xi > 0$ (and $R$ is real income). The key characteristic of (3.9) is that the income elasticity of marginal damage is simply $R/\xi$. Therefore, using (3.8), pollution rises with neutral growth if $R < \xi$ and falls with neutral growth if $R > \xi$. That is, we obtain an inverse-U relation between real income and pollution: pollution first rises and then falls as income rises. Environmental quality is a normal good throughout, but at low incomes, pollution rises with growth because increased consumption is valued highly relative to environmental quality. As income rises, the willingness to pay for environmental quality rises and increasingly large sacrifices in consumption are made to provide greater environmental benefits.

The income-effect explanation of the EKC follows from two assumptions: neutral growth and a particular assumption on preferences. Neutral growth restricts the magnitude of shifts in pollution demand as growth proceeds; while the rising elasticity of marginal damage to income ensures that ever strong technique effects are key to the result. Composition effects play little or no role. It is only variation in the willingness to pay for environmental quality that drives the result.

The income-effects explanation naturally suggests that the relationship between pollution and income should vary across pollutants according to their perceived damage. For example, we might expect a very low $\xi$ for directly life-threatening pollutants such as contaminated drinking

\textsuperscript{18} In a more general model, Lopez (1994) shows how the effects of growth on the environment depend on interaction between the elasticity of substitution between pollution and non-pollution inputs (which is equal to one in our model), and the income elasticity of marginal damage.
water. In this case, the EKC would be (almost) monotonically declining throughout; alternatively \( \xi \) might be very high for pollutants whose harm is uncertain or delayed. Carbon emissions may fit this category.

3.3 Threshold Effects

An alternative explanation for the EKC is based on threshold effects. Threshold effects can arise in either the political process as in Jones and Manuelli (1995), or in abatement opportunities as in Stokey (1998) and John and Pecchino (1994). Threshold effects lead to a very different relationship between income and pollution in early versus later stages of development. At low levels of economic activity, pollution may be unregulated entirely or regulation may have little impact on the profitability of abatement. Pollution therefore at first rises with growth. But after some threshold has been breached, and policy is either implemented or starts to bind, these models predict pollution declines with income - provided appropriate assumptions are imposed on tastes and technology.

There are at least two possible ways to ensure regulation is ineffective in checking pollution at low levels of income. The first is to assume an abatement production function where the marginal product of abatement is bounded. In this case, there will exist a set of relatively low pollution taxes for which firms choose the zero abatement option; consequently even though taxes may rise with growth over some range this has no affect on abatement and pollution rises with economic activity. An abatement function of this type was used in Copeland and Taylor (1994) and is implicit in Stokey (1998). The model we presented in Section 1 contains this attribute because we note from (2.6) if \( \tau < \alpha p \), no abatement occurs and \( e \) is unity. Pollution rises lock-step with output.

Alternatively we can assume a fixed cost to either abatement or policy. Suppose there is a fixed cost \( C_R \) of setting up a pollution regulation system. When national income is low, the aggregate willingness to pay to reduce pollution to its first best level may be less than the fixed regulatory cost \( C_R \), in which case it is not worth setting up a regulatory system. With no system in place, \( e \) is unity and pollution rises lock-step with output.
Both threshold theories need two further assumptions to generate an EKC. First we need an assumption on the growth process to restrict composition effects. This is typically done by adopting a one good framework or by limiting substitution possibilities by functional form assumptions. We will consider neutral growth. Second, we need an assumption on preferences to ensure that once abatement occurs, the response of pollution taxes is sufficiently income elastic. Given our previous demonstration, this requires an income elasticity of marginal damage in excess of one.

With these two assumptions in hand, consider the impact of growth via neutral technological progress. In the policy threshold model, the demand for pollution shifts out as technology improves and income rises. The net benefits of reducing pollution increase with income because we have assumed the elasticity of marginal damage with respect to income is greater than 1, and hence there will be a critical income level at which it is worth setting up a regulatory system. Further income gains then lower pollution. This simple model predicts a discrete improvement in environmental quality at the critical point; however, by introducing adjustment costs, we could obtain a smooth response.

In the abatement threshold model, pollution taxes rise with growth and eventually firms move off their corner solution. Abatement occurs and further increases in income drive pollution downward. Hence we obtain an inverse-U relation between pollution and income that is kinked at its peak.

Since threshold explanations also rely on income effects, they bear a close family resemblance to the income-effects explanation. Both explanations rely on a strong policy response to income gains as development proceeds, but they differ in their explanations for the initial rising segment. Threshold effect explanations predict a period of inactivity in pollution policy and/or private sector responses to policy; the income effect explanations predict small but increasingly tougher policies and higher pollution abatement costs over time.

### 3.4 Increasing Returns to Abatement

A final explanation for the EKC is increasing returns in abatement. The argument is
simply that as the scale of abatement rises its efficiency may increase. These efficiencies make abatement more profitable and hence even if pollution policy is stagnant and unchanging pollution can fall as more abatement is undertaken. Andreoni and Levinson (2000) develop this idea within a one good, endowment model and demonstrate how this process can lead to an EKC. This explanation carries with it an interesting twist on scale and technique effects because as the scale of output rises, even with constant pollution taxes, firms switch to cleaner techniques of production. The scale effect creates its own technique effect even with no pollution policy response to higher incomes. As such, this theory shares a common feature with the sources of growth explanation in that an EKC pollution profile is compatible with no change in pollution policy over the development path.

In Andreoni and Levinson's endowment model, issues of market structure arising from the increasing returns technology do not arise, but one can relatively easily extend their increasing returns to abatement explanation to allow for perfectly competitive firms by using either industry-wide learning by abating or by employing the methods of Markusen (1989) and introducing intermediate goods.

**The Role of International Markets**

Each of the theories we discussed above could generate an EKC with no international trade, but without trade it becomes more difficult for higher income countries to shed dirty production. Hence, it is useful to consider more explicitly how trade affects the EKC.

One key role for international trade is to offer an alternative abatement mechanism. Access to world markets offers an easy abatement alternative – import the good from abroad when higher pollution taxes make it more expensive at home. Consequently, trade makes pollution demand more elastic than otherwise: pollution is more responsive to changes in policy.

As well, international markets create links between country pollution levels, and this has important implications for the interpretation of the EKC. In the income effects explanation for the EKC, rich countries can reduce their pollution either by abating more or by using policy to encourage dirty industry to migrate to poorer countries. If the former process is the main driving
force, then all countries could follow a similar path. But if it is the latter, then even if an EKC exists, the experience of the current rich countries may not be replicated for newly industrializing countries.\footnote{See Arrow et al (1995).}

A natural concern is whether country-specific explanations are consistent with the overall cross-country evidence. One relatively uncharted branch of theoretical research is investigating whether one-country (or small open economy) explanations given for the EKC add up. That is, is there a fallacy of composition lurking in the background? At present, we know of no research addressing these concerns head on, but existing results in the literature suggest further work may be needed. For example, the Copeland and Taylor (1994) pollution haven model predicts a very different relation between growth and pollution in autarky than in free trade. If the income elasticity of marginal damage is one, the scale and technique effects of growth exactly offset each other in autarky, so growth has no effect on pollution. In contrast, in free trade, with the same preferences and technology, growth in the North raises both Northern and Southern pollution; and growth in the South lowers both Northern and Southern pollution. These results suggest that the impact of growth on the environment can be radically altered by interaction between countries. Further work along these lines should be useful.

### 3.5 The Empirical Evidence

The recent flurry of empirical work linking economic growth to environmental outcomes was fueled primarily by the work of Grossman and Krueger (1993, 1995).\footnote{In addition to Grossman and Krueger (1993,1995), other early contributions are Shafik (1994), Seldon and Song (1994), Hilton and Levinson (1998), Gale and Mendez (1996), and Berens et al. (1997).} As discussed earlier, they found that, after controlling for other non-economic determinants of pollution, measures of some (but not all) pollution concentrations at first rose and then fell with increases in per capita income. Their work is important in several respects: it brought the empirical study of aggregate pollution levels into the realm of economic analysis; it debunked the commonly held view that environmental quality must necessarily decrease with economic growth; and it provided highly
suggestive evidence of a strong policy response to pollution at higher income levels. 

Unfortunately, empirical research has progressed very little from this promising start. Subsequent empirical research has focused on either confirming or denying existence of similar relationships across different pollutants.\(^{21}\) This research has shown that the inverse-U relationship does not hold for all pollution, and there are indications the relation may not be stable even for any one type of pollution.\(^{22}\) Very little, if any, work has gone into evaluating the various hypotheses offered for the EKC.

In its original application, the EKC was interpreted as reflecting the relative strength of scale versus technique effects. However, it is difficult to support this interpretation. To isolate either the scale or technique effect we need to hold constant the composition of output, but this is not typically done in this literature. Therefore, the shape of the EKC must reflect some mixture of scale, composition and technique effects.

The EKC literature also has little to say so far about the effects of international trade on the environment. Although some authors have included measures of openness in EKC regressions to capture trade's effect, this approach is unlikely to be fruitful. As we will demonstrate in Section 3, both the pollution haven hypothesis and the conventional factor endowment hypothesis predict that openness to international markets has an environmental impact that varies with a country's comparative advantage. Therefore, we need to condition on variables indicating comparative advantage to find trade's effect. Simple measures of openness may capture some average effect across countries, but this is not likely to be very informative.

Despite these limitations, the major and lasting contribution of this literature is to suggest a strong environmental policy response to income growth. This has important implications for the empirical assessment of the effects of trade on the environment. The EKC studies are generally supportive of an approach where income gains driven by trade liberalization lead to policy changes in the long run. However, the literature has done little to clarify the causal

\(^{21}\) See, for example, Seldon and Song (1994), El-Ashry (1993), Harbaugh et al (forthcoming), Stern and Common (2001) and the surveys mentioned previously

\(^{22}\) Hilton and Levinson (1998) contains some of the most convincing evidence of an EKC. Harbaugh, et al. (forthcoming) examines the sensitivity of the original Grossman and Krueger finding to new data and alternative functional forms.
mechanisms involved. The usefulness of the EKC findings are limited unless we can distinguish between the various potential causes for the changes we see in pollution.

As our theoretical discussion has shown, an EKC is compatible with many different underlying mechanisms; two of which operate in the absence of any policy response to income gains, and one where changes in the composition of output are key to the result. While most studies do not present evidence allowing us to infer much about the underlying mechanisms, two recent studies offer additional insights.

Hilton and Levinson (1998) examine the link between lead emissions and income per capita using a panel of 48 countries over the twenty-year period 1972-1992. This study is important because it finds strong evidence of an inverted U-shaped relationship between lead emissions and per capita income, and then factors the changes in pollution into two different components. The first is a technique effect that produces an almost monotonic relationship between lead content per gallon of gasoline and income per capita. The second is a scale effect linking greater gasoline use to greater income. This study is the first to provide direct evidence on two distinct processes (scale and technique effects) that together result in an EKC.

To interpret the empirical evidence as reflecting scale and technique effects one needs to rule out other possibilities. Although the authors do not couch their analysis in this context, their analysis implicitly presents the necessary evidence. First, they document a significant negative relationship between the lead content of gasoline and income per capita (post 1983). This relationship shows up quite strongly in just a simple cross-country scatter plot of lead content against income per capita. We have depicted this in Figure 4 below.

Since lead content is arguably pollution per unit output, it is difficult to attribute the negative relationship in this figure to much other than income driven policy differences. Our

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23 Lurking in the background of this study is a composition effect operating through changes in the fleet of cars. This composition effect is not investigated in the paper, although it may be responsible for the jump in lead per gallon of gasoline use at low income levels shown in Figure 4 of the paper.

24 To be precise we should note that since lead content per gallon is an average, and cars differ in their use of leaded versus unleaded gas, the composition of the car fleet is likely to be changing as well. Therefore, the fall in average lead content may reflect an income -induced change in the average age of the fleet (which would lower average lead content) plus a pure technique effect.
Figure 4
interpretation is simply that regulation is tighter in higher income countries and this is driving down lead content (or $e$, emissions per unit output, in our framework).

Second, the authors find a hump-shaped EKC using data from the post-1983 period, but in earlier periods they find a monotonically rising relationship between lead emissions and income. The declining portion of the EKC only appears in the data once the negative health effects of lead had become well known. The emergence of the declining portion in the income pollution relationship is very suggestive of a strong policy response to the new information about lead. The fact this only appears late in the sample makes it difficult to attribute the decline in lead to other factors that could be shifting the demand for pollution. For example if the declining portion of the EKC was due to increasing returns to scale in abatement, then it should appear in both the pre and post-1983 data. If it was due to shifts in the composition of output arising naturally along the development path, why would it only appear in the post-1983 data? While it is possible to think of examples where these other factors are at play, the scope for mistaking a strong policy response for something else is drastically reduced in this study.

The natural inference to draw is that the decline only occurs late in the sample because with greater information about lead's health effects, policy tightened and pollution supply shifted upwards. Prior to this information, shifts in pollution supply were either absent or not sufficiently strong to lower overall emissions. Analytically, we could imagine that pre-1983 the damage of lead was viewed as low – i.e. if we were to adopt the income-effects explanation discussed earlier we would assume that in (3.9) $\xi$ is high – but post-1983, $\xi$ is low.

Finally, what about a role for international trade in determining pollution? Since lead emissions arise from domestic transportation use, it is highly unlikely that international trade could be responsible. That is, it is hard to imagine that changes in openness to world markets over this period shifted pollution demand in just such a way as to generate these results. With trade and other domestic factors eliminated as potential shifters of pollution demand, we are led to conclude that the declining portion of the EKC post-1983 reflects a strong induced policy response that more than offsets the scale effect.

The Hilton and Levinson (1998) study is important because it illustrates that policy responses can be very strong when the costs of pollution are well documented; in fact, it suggests
technique effects can easily swamp scale effects. It is also important from a methodological point of view because it illustrates how a clever methodology allows researchers to side-step the identification problems typically encountered in this literature.

A second important study is Gale and Mendez (1998). They re-examine one year of sulfur dioxide data drawn from Grossman and Krueger's (1993) study. The study does not offer a theory of pollution determination, but is original in investigating the role factor endowments may play in predicting cross-country differences in pollution levels. They regress pollution concentrations on factor endowment data from a cross-section of countries together with income-based measures designed to capture scale and technique effects. Their results suggest a strong link between capital abundance and pollution concentrations even after controlling for incomes per capita. Their purely cross-sectional analysis cannot, however, differentiate between location-specific attributes and scale effects. Nevertheless, their work is important because the strong link between factor endowments and pollution suggests a role for factor composition to affect pollution demand. That is, even after accounting for cross-country differences in income levels that may determine pollution supply, other national characteristics matter to pollution outcomes.

### 3.6 Summary

The EKC literature has expanded rapidly because of the ease of estimation and the potential relevance of its findings. Studies that replicate or extend the methods of early contributors have played a useful role in providing a check on the original work. But further work that simply estimates more EKCs has limited usefulness. Investigators must move beyond the methods that sparked the literature to methods useful in revealing the causal mechanisms underlying the relation between income and pollution.

To proceed further along these lines, more guidance from theory is needed. But unfortunately this guidance has not been provided by the existing theoretical work. This is because the existing theoretical literature is directed towards another goal – providing a theoretical explanation for the empirical EKC findings. As such, each approach has presented a different solution to the key problem we identified at the outset: if different countries grow in
different ways, there is no reason to expect any stable relation between per capita income and pollution. The source of growth explanation relies on composition effects; the threshold and income explanations rely on strong technique effects; and the IRS explanation from scale effects creating their own technique effect.

We would expect however that scale, technique and composition effects *all* play a role in determining the relation between growth and the environment. This suggests the focus on reduced forms linking only per capita income to pollution unlikely to be fruitful. If we are to ask more detailed questions of the pollution data, we will need different methods. And if we are to base policy recommendations on empirical work we will need to unpackage the Grossman and Krueger finding to identify the causal forces at work.

We suggest a step back from the EKC mindset to consider a theory determining the equilibrium level of pollution as a function of a relatively few factors. We have shown that in order to move from such a theory to the EKC explanations, we need to impose severe restrictions on either or both pollution supply and demand. This begs an important question. Starting from a position where observed pollution levels are taken to be an equilibrium outcome in a simple general equilibrium model, why should empirical research in this area continue to exclusively estimate highly restricted models? An approach that tries to disentangle the scale, technique and composition effects, and which allows these to vary across countries has much more support from theory and is more likely to generate an increased understanding of what drives the relation between growth and the environment.

4. **Trade Liberalization and the environment**

We now turn to the impact of international trade on the environment. We draw the usual trade theory distinction between trade and growth; that is, trade liberalization changes relative goods prices by opening up the economy to increased foreign competition; growth increases endowments or improves technology at given external prices. Trade induces a movement along a production frontier, whereas growth tends to shift out the frontier.
While this distinction is clear, it may not always be accurate. There is evidence that trade liberalization also stimulates economic growth; and at a theoretical level, trade can also alter the rate of growth if it spurs innovation or factor accumulation. In addition, trade may also either pave the way or alter the returns to labor and capital mobility and technology transfer. Hence, trade can set in motion forces that shift the production frontier as well. For clarity we will for the most part maintain the distinction drawn above.

We first examine the effects of trade on the environment in a small open economy facing fixed world prices to emphasize three major points. First, the effect of trade liberalization on the environment depends on a country's comparative advantage, which in turn depends on country characteristics. There is no reason to expect trade to have the same environmental effects on all countries. Second, the effects of trade on the environment depend on whether policy is rigid or responsive to the change in economic circumstances induced by the new trade regime as well as on the types of environmental policy instruments used by regulators. Finally, the welfare effects of trade liberalization are sensitive both to a country's comparative advantage and its policy regime.

We then examine a 2-region model to evaluate two the major hypotheses in the literature linking relative country characteristics to environmental outcomes: the pollution haven hypothesis, and the factor endowments hypothesis.

Since the focus of our discussion is on the effects of freer trade on the environment, we need to be specific in our model about the trade barriers that are being reduced. There are many different types of trade barriers. Some (such as tariffs) generate revenue; others, such as distance, generate productive activities such as transportation to overcome them; and yet others, such as bureaucratic delays and regulations simply create trading costs. At this point, we do not want to focus on the details of trade policy, but simply to capture in a very simple way the effects of increased opportunities to trade.

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To do so we assume there are some trade frictions between countries, which we capture by adopting an "iceberg" model of trade costs.\textsuperscript{26} That is, let $\delta$ be the fraction of good X lost to trading costs – if an exporter ships 1 unit of X, then $1-\delta$ units arrive.\textsuperscript{27} Trading costs drive a wedge between the domestic and foreign price of a good. Letting $p$ denote the world price of X as before, then the domestic price of X for an importing country is higher than the foreign price:

$$p^d_m = p(1 + \delta)$$

(4.1)

This is because to obtain one unit of X from the foreign country, a domestic consumer must order $1+\delta$ units. Competition in the domestic goods market will ensure domestic producers receive $p(1+\delta)$ as well (otherwise no imports would occur).

Conversely, if Home exports X, then to deliver a unit of X to a foreign market (where the price is $p$), a home exporter must send $1+\delta$ units, which are acquired locally at the domestic price $p^d_e$. Hence the domestic price is lower than the foreign price:

$$p^d_e = \frac{p}{1+\delta}$$

(4.2)

It will be convenient for us to sometimes simply use "$p^d$" to refer to the domestic price, but the reader should keep in mind that whether this price is above or below the world price depends on the country's comparative advantage. As trade frictions rise, trade is choked off, and for sufficiently high $\delta$, countries revert to their autarky equilibria. As trade frictions fall to zero, countries engage in free trade.

4.1 Rigid policy

Fixed emission intensities

The effects of trade liberalization on the environment depend on the environmental policy regime. We start with a simple case where government policy holds the emission intensity of

\textsuperscript{26} This approach has been frequently used in the trade literature. See for example, Samuelson (1954), and Dornbusch, Fischer and Samuelson (1977).

\textsuperscript{27} For simplicity, we assume there are no trade barriers for the numeraire good. This does not affect the qualitative results.
production fixed. This scenario is instructive because it simplifies the analysis by ruling out a technique effect, and may be a realistic approximation of policy in many countries (at least in the short run). Much pollution regulation tends to target emissions intensities, rather than overall emissions. Moreover, this approach includes the special case of no pollution regulation at all.

First consider a country importing the dirty good X. The domestic price is initially above the world price, and as trade frictions ($\delta$) falls, the domestic relative price of X falls. As with growth, we can decompose the effects of trade liberalization into scale, composition and technique effects. For convenience, we reproduce the decomposition from (2.17) here:

$$ z = e + \phi + S $$  

(4.3)

This is illustrated in Figure 5. Starting from point A, a trade liberalization reduces the domestic consumer and producer price of X. Production moves from point A to C, and pollution falls from $z_0$ to $z_2$. This change in pollution can be decomposed into a composition effect (A to B) which lowers pollution from $z_0$ to $z_1$, and a scale effect (B to C) which raises pollution from $z_1$ to $z_2$. As noted above, there is no technique effect in this example by assumption.

As shown, the scale effect is positive and tends to increase pollution. Trade increases production efficiency (measured at world prices), and this leads to more output, and hence more pollution. The composition effect is driven by the change in relative prices, which cause producers to shift towards the good whose relative price increases with trade. Because protection is being removed from the polluting good, the relative price of the clean good rises, and the share of clean good production in the economy rises. In our simple model where only one good pollutes, the composition effect always dominates the scale effect, because the economy moves along the production frontier, which has an unambiguous effect on the output of the polluting good.\(^{28}\) If the economy has a comparative advantage in clean goods, as in this example, trade is good for the environment in that it induces a shift away from dirty good production.

The pollution demand and supply diagram provides an alternative illustration of this result. In Fig. 6, we have drawn the pollution demand and supply curves as functions of the fixed

\(^{28}\) When both goods pollute, it is possible for the scale effect to dominate the composition effect.
Figure 5

Fixed Emission Intensity
ratio of $\tau/p^d$ (which is the simplest way in our framework to hold the emission intensity $e$ fixed).\footnote{The inverse pollution demand is $\tau = G_z(p^d,1,K,L,z)$, where the "1" refers to the price of the numeraire Y which we previously suppressed. But because $G$ is linearly homogenous in prices, we can divide by $p^d$ and rewrite the pollution demand as: $\tau p^d = G_z(1,1/p^d,K,L,z)$. This is downward sloping as usual.} With a fixed $e$, "pollution supply curve" is a flat line determined by the current fixed level of $e$.

Suppose the initial pollution demand curve is $D_0$. If Home imports $X$, a reduction in trade barriers stimulates the clean industry, drawing resources out of $X$. Consequently, the derived demand for pollution shifts left from $D_0$ to $D_1$. Pollution falls from $z_0$ to $z_1$. This corresponds to the movement from A to C in Figure 5.

Next consider the case where home exports $X$. In this case, the domestic relative price of $X$ price is initially $p^d_e = p/(1+\delta)$. Trade liberalization (a fall in $\delta$) now raises the domestic relative price of $X$. Producers shift along the production frontier towards the dirty good. This both increases the scale of production and shifts the composition of output towards the polluting good: both the scale and composition effects reinforce each other and lead to an increase in pollution. Referring to Figure 6, the derived demand for pollution shifts out from $D_0$ to $D_2$, pushing up the equilibrium level of pollution to $z_2$.

In summary, with fixed emission intensities, the composition effect is critical in determining the effects of trade liberalization on the environment. Moreover, the sign of the composition effect is ultimately determined by a country's comparative advantage. If a country has a comparative advantage in clean industries, then clean industries expand with trade; and conversely, if it has a comparative advantage in polluting industries, then dirty industries expand with trade.

**Fixed emission permits**

Now suppose the government uses a marketable emission permit system to regulate pollution, and that it does not adjust the supply of permits in response to changes in the trade regime. Earlier, we noted the the equivalence of permit and tax systems as a method of implementing the first best. But if we hold policy instruments fixed in the face of shocks to the economy, this equivalence breaks down.
Figure 6

Fixed Emission Intensities
Figure 7 illustrates the demand and supply for pollution in the presence of a fixed supply of pollution permits $z_0$. If $X$ is imported and we liberalize trade, then as we saw above, the derived demand for pollution will fall from $D_0$ to $D_1$ as producers shift towards the clean industry. For given emission intensities, this would reduce pollution. But because of the fixed supply of pollution permits, total pollution does not change. Instead the relative price of a pollution permit drops and producers switch to dirtier production techniques. This negative technique effect completely offsets the beneficial impact of the shift towards producing cleaner goods. Similarly, if $X$ is instead exported, trade liberalization leads to an (upward) adjustment in pollution taxes, but has no effect on pollution.

An important implication of this analysis is that the effects of trade on the environment depend on the type of regulatory instruments used. With rigid pollution taxes or emissions intensities, the environmental effects of trade liberalization may be quite substantial. But if pollution quotas are in place, the environmental effects of trade liberalization may be negligible.

**Welfare effects of trade liberalization**

The welfare analysis of trade liberalization in the presence of environmental problems draws heavily on the theory of the second best (Lipsey and Lancaster, 1956). Prior to trade liberalization, there are two types of distortions: trade barriers and inefficient pollution policy. Reductions in trade barriers can either alleviate or exacerbate the problems caused by inefficient pollution policy. Consequently, standard gains from trade theorems do not apply.

To determine the welfare effects of trade liberalization, consider the effects on the utility of the representative consumer of a small fall in the trade friction $\delta$. Differentiating (2.10) and substituting for $p$ with the trade-barrier inclusive domestic price yields:

$$\frac{dV}{V} = -Mdp^d + (\tau - MD)dz$$  \hspace{1cm} (4.4)

Trade liberalization has two effects on welfare: there are the standard gains from trade due to increased purchasing power, and there is the effect on the environment.\textsuperscript{30} While both importers

\textsuperscript{30} If we instead model trade barriers as tariffs ($\tau$), the welfare effects of trade liberalization can be written as $dV/V_f = \tau dM + (\tau - MD)dz$. A reduction in tariffs will raise imports, so the term $\tau dM$ represents the gains
Figure 7

Fixed Emission Levels
and exporters will experience direct gains from trade; the environmental effects differ as we saw above.

The standard gains from trade effect is always positive. If Home imports X, then $M > 0$ and the domestic price of X falls with trade liberalization. As a result $Mdp^d > 0$. If Home exports X, then $M < 0$ but the domestic price of X rises with trade liberalization. Once again we find $Mdp^d > 0$.

Changes in pollution can, however, potentially undermine the benefits of trade liberalization. To see this, suppose emission intensities are constant, and regulation is lax so that $\tau < MD$. Then if home exports X, pollution rises with trade liberalization. Because the pollution tax is less than marginal damage, this increase in pollution is welfare-reducing; that is, $(\tau - MD)dz < 0$. The net effect of trade liberalization on welfare is now ambiguous: the costs of increased pollution have to be compared with the benefits of increased goods consumption. If pollution is sufficiently damaging, then pollution costs will dominate and trade liberalization will reduce welfare.\(^{31}\)

On the other hand, if home imports X, trade liberalization may yield a double dividend by reducing pollution as well as generating increased consumption.\(^{32}\) With weak pollution regulation ($\tau < MD$), the economy gains from reduced pollution plus the standard gains from trade.

The instruments used also play an important role in determining the welfare effects of trade liberalization. If pollution regulation takes the form of a binding aggregate pollution quota, then trade must always raise welfare, even when marginal damage is high and pollution regulation is lax. Referring to (3.6) as long as the pollution quota is binding, pollution does not

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\(^{31}\) See Siebert (1977) for an early analysis of the welfare effects of trade liberalization in the presence of pollution.

\(^{32}\) The standard "double dividend" literature [see Bovenberg and de Mooij (1995) and Fullerton and Metcalf (1997)] considers the effects of pollution regulation in the presence of distortionary taxes on labour supply. That literature is also based on the interaction between two distortions.
change with trade liberalization, and hence we have \((\tau - \text{MD})dz = 0\). This leaves only the
standard gains from trade, which as we have already shown must be positive.\(^{33}\)

In summary, if pollution regulations are unresponsive to the trade regime, then the
welfare effects of trade liberalization depend on the pattern of trade, the type of policy instrument
used to regulate pollution, and the existing stringency of pollution regulation. If the number of
pollution permits is held fixed during trade liberalization, then freer trade has to raise welfare and
has no environmental consequences. But if emission intensity are unchanged with trade, then
trade increases pollution in countries with a comparative advantage in dirty goods, and reduces
pollution in countries with a comparative advantage in clean goods. And when pollution policy
does not fully internalize externalities, countries with a comparative advantage in dirty goods may
lose from trade.

4.2 Flexible policy

Now suppose government policy adjusts optimally in response to changes in the trade
regime. Pollution policy is determined by setting the marginal benefit of polluting equal to
marginal damage as in (2.14), where the goods price "\(p\)" is interpreted as the domestic price \(p^d\).
When trade is liberalized, the domestic price of \(X\), \(p^d\), changes. Trade affects both the marginal
benefit and the marginal damage of polluting. By differentiating (1.9) we obtain, after some
manipulation:

\[
dz = \frac{p^d M}{I} \left[ \frac{\epsilon_{MD,I}}{\Delta} \right] dp^d + \left[ \frac{\epsilon_{G,,p} - \epsilon_{MD,,p}}{\Delta} \right] dp^d, \tag{4.5}\]

where \(\Delta > 0\), \(M\) denotes net imports, and each of the elasticities is positive. This divides the
effects of the change in the domestic price of \(X\) into two components: the first term is an income
effect, and the second is comprised of two substitution effects.

---

\(^{33}\)See Copeland (1994) for further details on trade policy reform in a world with many goods and pollutants.
With pollution quotas in place, uniform tariff reductions will increase welfare, but with pollution taxes (or
fixed emission standards), then the welfare effects of trade liberalization depends on whether trade
protection is biased towards clean or dirty goods. Beghin et al. (1997) uses a similar approach to investigate
First consider the income effect. Because trade liberalization raises real income and environmental quality is a normal good, the income effect will always tend to reduce pollution. That is, the pollution supply curve shifts back due to the income effect of trade liberalization. This is true for both importers and exporters of the dirty good, and can be verified by noting that $M_d p_d < 0$. For a dirty good importer, $M > 0$ and $p_d$ falls; and for a dirty good exporter, $M < 0$ and $p_d$ rises. The strength of this effect depends on the income elasticity of marginal damage, $e_{MD,I}$, which we previously saw played a critical role in determining the effects of growth on the environment.

The substitution effects of trade liberalization, however, move in opposite directions for dirty good importers and exporters. There are two substitution effects, one in production and the other in consumption. On the production side, an increase the price of the dirty good stimulates production of the dirty good, and this tends to increase the demand for pollution. This substitution towards dirty good production creates both scale and composition effects that raise the pollution level, ceteris paribus.

On the consumption side, an increase in the price of the dirty good raises consumption prices relative to the cost of environmental quality. Consumers would like to substitute towards more environmental quality and the policymaker responds by raising the pollution tax (the pollution supply curve shifts back for a dirty exporter). Therefore the two substitution effects work against each other.

In general the strength of these two offsetting forces is ambiguous as different assumptions on utility and production structure can make one or the other dominate. The magnitude of the consumption substitution effect is, not surprisingly, proportional to share of the dirty good in overall income; the magnitude of the production side substitution effect dominates in our framework here because of the strong relationship between product and factor prices in the Heckscher-Ohlin model. Therefore, in our simple model, the net substitution effect tends to increase pollution for a dirty good exporter and reduce pollution for a dirty good importer.

Putting the substitution and income effects together, we can determine the impact of trade liberalization on pollution. For a dirty good importer, trade liberalization will reduce pollution. The increase in income shifts back pollution supply, and the lower price of dirty goods leads to a
reduction in pollution demand. Both income and substitution effects therefore combine to improve environmental quality.

On the other hand, for a dirty good exporter, pollution tends to rise via the substitution effect (the demand for pollution rises as the price of the dirty good rises), but tends to fall via the income effect (the supply of pollution shifts back as real income rises). The income effect is particularly critical. If the income elasticity of marginal damage is small, then pollution rises in a dirty good exporting country, even though pollution policy is fully optimal. Conversely, if the income elasticity of marginal damage is sufficiently high, then pollution falls.

To get a sense of what we mean by "large", one can show that if $e_{MD,I} \leq 1$, then pollution will rise in a dirty good exporter. In particular, pollution rises if $e_{MD,I} = 1$. Now recall our results in section 3.2. Neutral economic growth had no effect on the environment when $e_{MD,I} = 1$. Therefore income growth via trade liberalization and income growth via neutral progress differ in their environmental consequences.

The key to these differences is composition effects, just as it was the key to the results we found in section 3.1 – the source of income growth matters. Trade liberalization creates an income gain when countries alter their production patterns in response to changed domestic prices. That is, income growth in trade is typically reliant on a composition effect. When this composition effect is biased towards the dirty industry – as it is for a dirty good exporter – then it is more difficult for pollution to fall with trade-induced income gains. When this composition effect is biased towards the clean industry – as it is for a clean good exporter – it is relatively easy for pollution to fall with trade-induced income gains.

Our other results from section 3 can also matter here. For example if the income elasticity of marginal damage is increasing in real income (as it was in our example in 3.2), then we might expect pollution to rise in a low income dirty good exporter, but fall in a high income dirty good exporter. As well, we would expect the policy response to differ across pollutants, because both income and substitution effects will vary with the importance of each type of pollutant in production and with the type of damage caused. In addition, the impact of trade liberalization would also differ in settings where the policy process was subject to threshold
effects or if abatement exhibited increasing returns. We know however of no research investigating either of these channels.

**Welfare effects of trade liberalization with efficient policy**

When policy is set optimally, then \( \tau = MD \) and the effect of trade liberalization on welfare in (4.4) reduces to

\[
\frac{dV}{V} = -Mdp^d \geq 0.
\]

We are left with the standard gains from trade. If pollution externalities are fully internalized, trade must always increase welfare. Trade may lead to an increase in pollution if the economy has a comparative advantage in pollution, but this reflects an optimal tradeoff between environmental quality and consumption. If a country has a comparative advantage in polluting goods, then it can obtain higher prices for these goods in export markets than at home. This means that the opportunity cost of preserving the environment rises as trade as liberalized, because consumers are now able to obtain more from foreigners from the exploitation of their environment than they were willing to pay to preserve it. The policymaker responds by allowing increased exploitation of the environment. Provided externalities are fully internalized, this must improve welfare.

### 4.3 The Determinants of Comparative advantage

It should now be apparent that composition effects play a key role in determining the effects of trade on the environment. But composition effects depend on a country's comparative advantage and hence a major pre-occupation of the literature has been an investigation of which countries attract dirty industries when trade is liberalized.

There are two major competing theories, although they are often not stated explicitly. The *pollution haven hypothesis* predicts that countries with relatively weak environmental policy will specialize in dirty industry production. In many versions of this hypothesis, countries with weak environmental policy are also low-income countries. An alternative hypothesis is that
environmental policy has little or no effect on the trade pattern: instead standard forces, such as differences in factor endowments or technology, determine trade. For example, under this view capital abundant countries tend to export capital-intensive goods, regardless of differences in environmental policy. We will call this the factor endowments hypothesis, although it can be interpreted more broadly to encompass other motives for trade, such as technology differences.

We can illustrate these competing theories within our simple model by assuming there are two regions in the world: "North" and "South". We use an asterisk ("*") to denote Southern variables. North and South may have different factor endowments or pollution policy, but we assume they are otherwise identical.\textsuperscript{34}

The interaction between factor endowments and pollution policy in determining the pattern of trade can be illustrated using a simple relative supply and demand analysis to determine autarky prices in each country. To construct relative demand, note that given our assumption that preferences over goods are homothetic and separable from environmental quality, the demand for $X$ can be written as $b_x(p)I$, and the demand for $Y$ as $b_y(p)I$ where the $b_i$ depend only on $p$,\textsuperscript{35} and $I$ is national income for the relevant country. Consequently, the demand for $X$ relative to $Y$ is independent of income and downward sloping since $b_x$ is decreasing in $p$, and $b_y$ is increasing in $p$. That is:

$$RD_{X/Y}(p) = \frac{b_x(p)}{b_y(p)},$$

(4.6)

where $RD'(p) < 0$. Moreover, because preferences are identical across countries, the relative demand curve is the same in each country. This is illustrated in Figure 7 as the curve labeled $RD$.

Next, we need to determine the relative supply curves for each country. Using (2.7) and exploiting constant returns to scale, we can write relative supply as a function of $K/L$ and the emission intensity $e$:

\textsuperscript{34} It is easy to allow for other differences between countries. We rule out other differences here to highlight the interaction between the pollution haven and factor endowment motives for trade.

\textsuperscript{35} Note that the role of $p_y$ has been suppressed in $\beta$ because we set $p_y = 1$. Note however that $\beta$ depends on both prices, so with slight abuse of notation, we could have written $\beta(p_x,p_y)$. Then using Roy's Identity, we obtain $b_x(p) \equiv \beta(p_x(p,1)/\beta(p,1)$, and $b_y(p) \equiv \beta(p_y(p,1)/\beta(p,1)$.
Figure 8

Pollution Haven Hypothesis
\[ \text{RS}(p,e,K/L) = \frac{x(p,e,K/L,1)}{y(p,e,K/L,1)}. \] (4.7)

This yields a standard upward-sloping relative supply curve (increases in \( p \) increase the supply of \( X \) relative to \( Y \)). Because North and South differ in factor endowments and emission intensities, their relative supply curves will also differ. Figure 7 illustrates a couple of relative supply curves, labelled RS and RS*.

The intersection of relative supply and demand curves determines autarky prices for each country, and we can then use these differences in autarky prices to infer the pattern of trade. We will use this model to consider the pollution haven and factor endowment hypotheses separately, and then consider how they interact with each other.

**Pollution haven hypothesis**

The simplest version of a pollution haven model can be obtain by assuming that countries are identical except for exogenous differences in pollution policy. Pethig (1976) used a Ricardian model in which countries differ only in exogenous emission intensities and showed that the country with weaker policy would export the polluting good. Chichilnisky (1994) assumed exogenous differences in the property rights regime – poor countries are simply assumed to have no property rights assigned to environmental resources, while rich countries have perfect policy.

Referring to Figure 8, suppose North and South are initially identical. Then the two countries would have the same relative supply curve, which we illustrate as RS. Autarky prices would be the same, and there would be no trade. Now suppose South's emission intensity rises; that is, consider the effect of weaker pollution policy in the South than North (\( e^* > e \)). South's higher emission intensity will stimulate its X industry and contract Y (because resources move out of Y into X). This tells us that the country with the weaker pollution policy (i.e., higher \( e^* \)) produces relatively more X for any given p; that is, South's relative supply curve will shift out to the right, as illustrated by RS*.

\[ ^{36} \text{As above, we assume that the government use tax policies to implement its emission intensity targets.} \]
We can therefore conclude that the autarky relative price of X is higher in the North than in the South: \( p^A > p^{A*} \). North has a comparative advantage in the clean good. The intuition is straightforward. Because North taxes pollution more heavily, relatively less of the polluting good is produced there, which pushes up its autarky price. This will generate trade. Once trade is opened, Northerners will import X from the South, and Southerners will import Y from the North. This contracts dirty good production X in the North and stimulates it in the South.

Moreover, because we have assumed that each country holds emission intensities fixed, pollution moves in the same direction as X. Pollution rises in the country with weak pollution policy (here the South), and falls in the country with strict pollution policy (here the North). Trade induced by pollution policy differences creates a pollution haven in the country with weaker policy.

The welfare effects of such trade depend on the stringency of pollution policy, as we discussed in the previous section. If pollution policy is too weak, North must gain from trade, both because of an increase in purchasing power and because of the fall in pollution. South, however, may lose. Its income rises, but so does pollution. And if externalities are not fully internalized, the increase in pollution is harmful to the South.

The predictions of this simple pollution haven model are consistent with the concerns of some of the critics of freer trade. North gains from trade by offloading some of its polluting production onto the South. Moreover, this model also predicts an increase in global pollution - production in the dirtiest industry is shifted to the parts of the world with weaker environmental policy. This "global composition effect" tends to raise world pollution.

**Exogenous differences in policy: Emission permits**

As one might expect given our earlier discussion, the effects of pollution havens are sensitive to the pollution policy regime. Suppose instead that each country uses emission permits, as in Rauscher (1991). As before, let North be more tightly regulated that the South, so that \( z < z^* \), where \( z \) and \( z^* \) are the exogenous aggregate pollution quotas in North and South. Then if countries are otherwise identical, the equilibrium price of a pollution permit in autarky is higher in the North than in the South. Consequently, South's relative supply curve will
be to the right of North's, as in Figure 8. This will gives the South a comparative advantage in dirty goods as before.

When trade in goods is opened, North will export the clean good Y and import the dirty good X. But there is no change in the equilibrium level of pollution in either country. Instead, there is a convergence of pollution permit prices. Permit prices fall in the North, as the X industry contracts there; and the price rises in the South as the polluting industry expands there. Northern and Southern permit prices converge because trade in goods provides an indirect way for permit holders to compete with each other across countries. Moreover, because there is no change in pollution, both countries must gain from trade.

This example is instructive in several ways. It shows how the South can be a pollution haven because of its lax policy and yet necessarily gain from trade. Moreover, although the fraction of South's output accounted for by dirty good production rises with trade, its aggregate pollution is unaffected (because a technique effect fully offsets the composition effect).

As well, this example can help clarify a point raised by Chichilnisky (1994). Chichilnisky introduces the terms "actual" and "perceived" comparative advantage and claims that trade based on perceived comparative advantage cannot benefit the South. In our context (and hers) South has a perceived comparative advantage in dirty goods; that is, it only arises because of a departure from first-best pollution policy. The South does not have an actual comparative advantage – because in the first-best North and South are identical.

The trade that occurs in our example and in Chichilnisky's model is driven only by perceived comparative advantage. No trade at all would occur in the first best. But although such trade can sometimes harm the South (as in our emission intensity example), it can also benefit both countries (as in our permit example). That is, knowing only that trade is created by inefficient pollution policies is not sufficient to conclude that such trade is harmful.

**Endogenous pollution havens: Income-induced policy differences**

A weakness of pollution haven models with exogenous policy is the exogenous policy. Although authors often motivate the pollution policy differences by income differences – such as
a North-South income gap – pollution policies in these models do not respond when trade alters income levels. At best we should think of these as short run models; at worst they contain a logical contradiction. The lack of a policy response affects both the positive and normative effects of trade even within a pollution haven-trading situation. To address this issue, we use our model to illustrate a simple version of the Copeland/Taylor (1994) pollution haven model where endogenous income-induced policy differences create, and, respond to, trade.

Consider two countries differing only in the scale of their endowment vector. That is, \( K = \lambda K^* \) and \( L = \lambda L^* \), where \( \lambda > 1 \). We also assume each country has the same number of consumers (which we normalize to one), so increases in \( L \) should be thought of as an increase in the supply of effective labor. Therefore, North’s workers are more highly skilled than South’s but the ratio of capital to effective labor is the same in both. This means that North is richer than South, but because the \( K/L \) ratios are the same across countries, there is no incentive to trade in the absence of pollution policy.

We assume that the regulator acts as a price taker in world goods markets when choosing pollution policy. The optimal pollution tax is equal to aggregate marginal damage and is given by (2.13), which we reproduce here:

\[
\tau = N \cdot \left[ -\frac{V_z}{V_I} \right] = N \cdot MD(p, R, z). \quad (4.8)
\]

Because environmental quality is a normal good, the country with higher income chooses a higher pollution tax for any level of pollution and goods prices. These income-induced differences in environmental policy create an incentive to trade. To demonstrate, refer to the relative supply curve given by (4.7). North and South have the same \( K/L \) ratio, but North’s higher income means that its emission intensity is lower (\( e < e^* \)). Consequently, North’s relative supply of \( X \) is to the left of South’s for any given \( p \). Figure 8 can therefore be used to infer the trade pattern again. North’s high income gives it a comparative advantage in the clean good. When trade is opened, North will export the clean good (\( Y \)) and import the dirty good (\( X \)).

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37 That is, we assume that the regulator does not employ pollution policy to strategically manipulate the terms of trade in the goods market. This assumption is reasonable if we think of our model as a proxy for a world with many small Northern and Southern countries. We will, however, turn to the strategic trade policy issues later in this essay.
polluting industry will contract in the North and expand in the South. The low income country becomes a pollution haven.

The effects of trade on pollution can be inferred from our earlier results. Pollution falls in the North, as both the substitution and income effects of trade liberalization induce the policy maker to choose less pollution. Pollution will rise in the South as long the income effect is not too strong. Moreover, if income effects are not too strong, world pollution can rise with trade as well because the dirtiest industries shift to the country with weaker policy. But because both North and South fully internalize pollution externalities, trade liberalization is always welfare increasing for both countries: income-induced policy differences are an efficient source of comparative advantage.

Overall, pollution haven models are consistent in their prediction that freer trade leads the country with weaker pollution policy to export the dirty good. In a model with endogenous policy, they predict that the low income country has weaker policy and therefore the low income country will export the dirty good. The effects of such trade on pollution and welfare, however, depend on the policy regime, as we have discussed above.

A major weakness of the pollution haven models, however, is that they assume that policy differences are the only motive for trade. Our preferred interpretation of these models is that they have identified one of the key channels via which trade can affect the environment. The full effect of trade on the environment is determined by the interaction between the pollution haven motive for trade with other motives.

Factor endowments hypothesis

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38 In particular if the elasticity of marginal damage with respect to income is less than or equal to one, then pollution rises with trade.

39 The result that the South necessarily gains from trade despite the concentration of polluting activities in the South is critically dependent on the assumption that all externalities are fully internalized. In practice this may be difficult to achieve. Full internalization means the pollution tax reflects all costs of environmental damage, including effects which are notoriously hard to measure, such as the effects on future generations, long run effects on the ecosystem, and effects on biodiversity and wilderness conservation. South could lose from trade if any of these costs are not internalized.
The principal alternative to the pollution haven hypothesis is what we have called the factor endowments hypothesis. We illustrate this in Figure 9. Relative demand (RD) is as before. Referring again to (4.7), to isolate the pure factor endowment hypothesis, suppose that emission intensities are identical and exogenous across countries, but that relative factor endowments differ. Specifically, suppose that North is relatively capital abundant so that $K/L > K^*/L^*$.

Let $RS^*$ denote South's relative supply curve. Because X is capital intensive and emission intensities are held constant, then via the Rybczinski Theorem of international trade, North's capital abundance pushes its relative supply curve (RS) out to the right of South's. Hence the autarky relative price of X is lower in the North than in the South. With identical and exogenous pollution emission intensities across countries, the capital abundant country (North) exports the capital-intensive (dirty) good. Trade expands the polluting, capital-intensive industry in the capital abundant country (the North), and pollution rises in the North. Conversely, pollution falls in the capital scarce country (the South) as the polluting industry contracts there.

Although we have illustrated the factor endowments hypothesis with a very simple example based on capital abundance, the key insight is that the impact of trade on the environment depends on a country's underlying production capabilities. Countries relatively abundant in factors used intensively in polluting industries will on average get dirtier as trade liberalizes, while countries that are relatively abundant in factors used intensively in clean industries will get cleaner with trade.

The predictions of this theory contrast sharply with those of the pollution haven hypothesis. If the factor endowments hypothesis is correct, there need be no link between a country's income and how trade affects it environment. If a poor country is abundant in factors used intensively in clean industries, then the poor country's pollution will fall as trade is liberalized.

**Factor endowments and endogenous policy differences**

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40 That is, we assume that $\tau/p$ is identical across countries.
Figure 9

The Factor Endowments Hypothesis
We have illustrated the pollution haven and factor endowment hypotheses in isolation, but of course countries differ in both their pollution policy and in their factor endowments. Rich Northern countries are likely to be both capital abundant and have stricter pollution policy than poorer Southern countries. North's strict pollution policy will tend to make it a dirty good importer, but its capital abundance tends to make it a dirty good exporter. The pattern of trade depends on which of these effects is stronger.\textsuperscript{41}

If relative factor endowments are similar but North is richer than South, then pollution haven effects dominate and North exports the dirty good. But if relative factor endowment differences are sufficiently strong in comparison to relative income differences, then North will export the dirty good, despite having more stringent environmental regulation than the poor South.

Since this result reverses the pattern of trade under the pollution haven hypothesis, it has a number of important implications. When North is sufficiently capital abundant, trade will lead to an expansion of the dirty industry in the North, despite North's stricter pollution regulation and higher income. Although North's stricter environmental regulations do raise Northern production costs in \(X\), this is more than offset by the relative abundance of factors used intensively in \(X\). Trade need not induce dirty industry migration from rich to poor countries, and in fact can lead to the opposite conclusion.

Moreover, this implies that if North is sufficiently capital abundant, and if the income elasticity of marginal damage is not too high, then trade will raise pollution in the North and lower it in the South. On the other hand, if the income elasticity of marginal damage is sufficiently high in the North, it is possible that trade may reduce pollution in both North and South. This will occur if North's pollution supply shifts back far enough to offset the increased pollution demand induced by trade.

\textsuperscript{41} The interaction between income differences and relative factor endowments in determining the pattern of trade is analyzed in Copeland and Taylor (1997), Richelle (1996), and Antweiler, Copeland and Taylor (2001).
Finally, even if Northern pollution does not fall, trade shifts dirty good production from the country (South) with weak pollution regulation to the country (North) where regulations are more stringent. This global composition effect tends to reduce global pollution. This contrasts with the pure pollution haven model where trade tended to increase global pollution by shifting dirty good production to countries with weak emission standards.

**Comparative Advantage Summary**

As we have shown, the effects of trade on both the local and global environment depend on the distribution of comparative advantage across countries. Moreover, comparative advantage is determined jointly by differences in pollution policy and other influences, such as differences in factor endowments.

Pollution havens need not emerge from trade if rich countries tend to be relatively abundant in factors used intensively in pollution-intensive industries. And if this is the case, then trade may lead to both a cleaner environment in poor countries, as well as a reduction in global pollution. It also means differences in pollution policy alone do not imply dirty industries will migrate to poor countries as a result of trade. Therefore concerns about the loss in competitiveness in polluting industries may be misplaced.

For some types of industries, we would expect the role of factor endowments to reinforce those of pollution policy. Polluting industries that are intensive in unskilled labor or in natural resources may well be attracted to low-income countries both by natural resource abundance and less stringent policy. We should expect to find heterogeneity across industries as well as countries in the roles played by policy and factor endowments differences. Even if rich countries do have a comparative advantage in dirty industries because of their factor abundance, this does not mean pollution policy is irrelevant for trade patterns. As our analysis indicates, for given levels of relative capital abundance, increases in the stringency of pollution policy will tend erode

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42 For a formal demonstration of this result, see Copeland and Taylor (1997) and Richelle (1996).
a country's comparative advantage in dirty goods and tend to reduce dirty good exports. Regulations are not irrelevant.

4.4 The Empirical Evidence

We now consider the empirical evidence on the effects of trade on environmental outcomes. To limit the scope of our discussion, we focus here only on the empirical evidence linking liberalized trade with industrial pollution. By doing so we exclude discussions of empirical work linking trade to changes in renewable resource stocks, and to consumption-generated pollution such as carbon emissions. We also do not discuss the literature on the effects of environmental policy on plant location. 43

The literature has not always been clear about the hypotheses being tested. However, the pollution haven hypothesis has received the most attention. Under this hypothesis, free international trade leads to the relocation of dirty good production from stringent regulation countries (the North) to lax regulation countries (the South). 44 An often-stated corollary is that pollution-haven-driven trade raises pollution in the developing Southern countries and lowers it in developed Northern countries.

The major alternative to the pollution haven hypothesis relates conventional determinants of comparative advantage - factor endowments and differences in technology - to comparative advantage and trade flows of dirty goods. This conventional view was behind Grossman and Krueger's (1993) evaluation of NAFTA and references to it appear in numerous other studies. In our theory section, we presented one version of this view: the factor endowments hypothesis. If we rule out (non-neutral) differences across countries in technology and assume dirty good production is capital intensive, then the conventional factor endowments hypothesis is that free international trade leads to the relocation of dirty good production from capital scarce countries to

43 For earlier reviews, see Levinson (1996) for a survey of the literature on plant location, and Jaffe et al (1995) for a survey that reviews the empirical literature on the effects of environmental policy on plant location and trade in the US. We discuss some of the papers reviewed by Jaffe et al., but our interpretation of their results differs in some cases.

44 The pollution haven hypothesis sometimes goes under the name of dirty industry migration, and is loosely related to the possibility of a race to the bottom in environmental stringency.
capital abundant countries. A corollary is that pollution levels should fall in capital scarce countries and may rise in capital abundant countries.

The reader should be warned that nowhere in the literature is there a formal test of either hypothesis, nor is there a discussion of what such a test would look like. Many studies do present evidence that is suggestive of one hypothesis or the other, but no one to date has extended either hypothesis to a many-country framework – seemingly necessary for empirical testing – nor has anyone combined cross-country information on technology, incomes, factor endowments, and pollution regulations which would be necessary for a formal test.

Instead we are left with a series of interesting findings arrived at by a variety of methods that bear to a greater or lesser extent on our hypotheses. Our job here is to piece together this information to provide a suggestive weighing of the evidence for and against the hypotheses. To anticipate our conclusions, the evidence is at present ambiguous. Apart from specific case studies, there is very little evidence linking liberalized trade with significant changes in the environment. In addition, there is little evidence that differences in abatement costs are a significant determinant of trade flows. There is, however, quite convincing evidence from a variety of sources that increases in income will, after some point, lead to lower pollution concentrations. The role trade plays in creating this income gain is, however, not entirely clear.

This unsatisfactory state of affairs is the result of several factors. First, and foremost is the availability of data. Pollution data are very scarce. This scarcity has had a large impact on the evolution of the empirical literature. It has led numerous authors to conduct analyses using constructed data, and has left virtually untouched other areas of research desperately in need of investigation.

A second serious challenge arises from the nature of the questions addressed. Most empirical studies are interested in measuring the impact of government regulation. The regulation may be a pollution tax, a decline in tariffs, or the imposition of a standard that drives pollution abatement costs upwards. This focus on policy impacts is perhaps natural since the major hypothesis in the literature – the pollution haven hypothesis – makes a direct causal link between pollution policy differences and economic outcomes. But policy analysis is a tricky business, since variation in policies over time and across industries often reflects, as well as
determines, economic outcomes. As a consequence, the literature’s success at evaluating policy impacts is limited.

The literature’s international context also presents difficulties. Both major hypotheses relate cross-country differences in characteristics to comparative advantage and trade flows. This fact virtually necessitates a cross-country analysis, but this severely magnifies the data problem. Compounding this difficulty is that any credible examination of the pollution haven hypothesis needs data from some of the world’s poorest countries. These countries however have the least developed methods of accounting and monitoring.

A final contributing factor has to be the unwillingness of researchers to bring theory to bear in their investigations. While it is surely true that data limitations have made it difficult to identify key empirical magnitudes, this does not rule out a role for even very simple theories to inform the data analysis. To drive this point home we provide at several points quite rudimentary analyses suggesting deficiencies and problems with the current empirical literature. These analyses are not meant to substitute for full-fledged study of the issues involved, but merely to reinforce the illuminating role theory can play.

In the following sections we describe and critique the methods and results from the empirical literature. To do so, we employ the models discussed in the earlier parts of this essay. Throughout we suggest reasons for the disparate and sometimes weak findings, and present suggestions for future research.

**Dirty Industry Migration or Development?**

The first analyses in this area were relatively simple statistical exercises constructing and evaluating trends in “dirty good” production, consumption, or trade. Given the lack of good cross-country pollution data, this literature “solves” the data problem by first classifying industries into the categories dirty or clean, and then constructing a broad cross-country panel of data on dirty and clean imports, exports, output etc. for analysis. The categorization into dirty and clean is typically based on U.S. data. Industries may be categorized on the basis of their
emission intensity (emissions per $ of output), toxic intensity (physical releases per $ of output),
or on the level of pollution abatement costs as a fraction of value-added.

While this method is clearly not ideal, it has its strengths. For example, the set of dirtiest
manufacturing industries appears to be fairly stable across both countries and pollutants.
Therefore, identifying a dirty industry may not be that difficult. For future reference, we present
the top ten dirty (manufacturing) industries ranked by air, water and metals discharges. The data
in Table 1 are drawn from Mani et al. (1997).

[insert table 1]

Given the similarities in the rankings across air, water, and metals discharges it appears
that identifying the dirtiest manufacturing industries is relatively simple. The five dirtiest sectors
often selected for intensive study are: Iron and Steel (371), Non-Ferrous Metals (372), Industrial
Chemicals (351), Pulp and Paper (341), and Non-Metallic Mineral Products (369). Using the
same methods to identify clean sectors, Mani et al. (1992) classifies textiles (321), non-electrical
machinery (382), electrical machinery (383), transport equipment (384), and instruments (385) as
the five cleanest sectors in U.S. manufacturing.

Under the assumption that this categorization of manufacturing industries into dirty and
clean holds across both time and space, researchers construct the cross-country data needed for
their analysis. Taking these new data as their dependent variable, these studies proceed by
linking variation in dirty and clean good trends to country characteristics such as income, income
growth or openness. The analysis may employ simple summary statistics such as Balassa
revealed comparative advantage measure, or employ regression analysis to explore the sensitivity
of the series to several potential determinants. In all of these studies, researchers are searching
for pollution havens and therefore income differences, income growth rates and measures of
openness are the prominent explanatory variables.

An immediate limitation of these studies is apparent: by measuring trends in dirty
industry output rather than pollution levels, they have necessarily assumed changes in the
composition of a country’s output correspond to changes in environmental quality. But if the
techniques of production change over time because of trade, income growth or technological
progress then a greater share of dirty good output is consistent with both greater and lesser
### Table 1

**Ranking of the Dirtiest Manufacturing Industries**

<table>
<thead>
<tr>
<th>Rank</th>
<th>Air</th>
<th>Water</th>
<th>Metals</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Iron and Steel</td>
<td>Iron and Steel</td>
<td>Non-Fer. Metals</td>
<td>Iron and Steel</td>
</tr>
<tr>
<td>2</td>
<td>Non-Fer. Metals</td>
<td>Non-Fer. Metals</td>
<td>Iron and Steel</td>
<td>Non-Fer. Metal</td>
</tr>
<tr>
<td>5</td>
<td>Pulp and Paper</td>
<td>Industrial Chemical</td>
<td>Pottery</td>
<td>Non-Met. Min.</td>
</tr>
<tr>
<td>6</td>
<td>Petro. Refineries</td>
<td>Other Chemicals</td>
<td>Metal Products</td>
<td>Pulp and Paper</td>
</tr>
<tr>
<td>7</td>
<td>Industrial Chemical</td>
<td>Beverages</td>
<td>Rubber Product</td>
<td>Other Chemical</td>
</tr>
<tr>
<td>8</td>
<td>Other Chemicals</td>
<td>Food Products</td>
<td>Electrical Products</td>
<td>Rubber Products</td>
</tr>
<tr>
<td>9</td>
<td>Wood Products</td>
<td>Rubber Products</td>
<td>Machinery</td>
<td>Leather Products</td>
</tr>
</tbody>
</table>

*Source: Mani et al. (1997, p4)*
pollution levels. By itself, changes in the composition of output tell us relatively little except perhaps in the short run when emission intensities are fixed. Since many of these studies cover quite significant stretches of time, skepticism is in order. At best this method may be able to identify a compositional shift consistent with the pollution haven hypothesis, but never reveal its environmental consequences.\footnote{A simple counter-example is provided by our two-country model with a fixed number of emission permits. Recall the lax regulation South would change the composition of its output towards dirty goods, but emissions were left unaffected by trade.}

A second concern is that since the composition of national output is affected by many factors, researchers in search of pollution havens run the risk of attributing any change in the composition of output to pollution haven driven trade rather than some altogether distinct domestic process. This risk is magnified by the literature’s avoidance of theory - which would naturally suggest alternative hypotheses - and its almost single-minded focus on income levels as a determinant of changing trade patterns. We view this concern as the literature’s major weakness.

Despite these limitations, several authors have employed these methods to conclude, sometimes tentatively, that the rise in environmental control costs in the developed world has led to the creation of pollution havens in the South.\footnote{Xu (1999) finds little statistical evidence for a change in competitiveness based on a primarily OECD sample. The raw data however indicate that for OECD countries, environmentally sensitive goods have fallen from 24\% of exports in 1965 to 18\% in 1995; whereas for the “other” category these shares have moved from 18\% in 1965 to 22\% in 1995. See Table 1, p. 1219.} For example, Low and Yeats (1992) find that over the 1965-1988 period the share of dirty goods in exports from industrial countries fell from 20\% to 16\%, but over the same time the share of dirty goods in exports from many poor developing countries rose.\footnote{See Table 6-2, p94. Developing country reliance on dirty good exports varies by region. In Eastern Europe the percent rises from 21\% to 28\%; in Latin America from 17\% to 21\%; in South-East Asia the share of dirty goods exports in total exports is flat at 11\%; and in West Asia it rose from from 9.2\% to 13\%.}

Other researchers, employing slightly different country groups and methods, corroborate these findings. Ratnayake (1998) in a study of New Zealand’s trade patterns notes that in 1980, 96\% of its imports of dirty goods came from the OECD, but by 1993 this had dropped to 86\%.\footnote{For example, Low and Yeats (1992) find that over the 1965-1988 period the share of dirty goods in exports from industrial countries fell from 20\% to 16\%, but over the same time the share of dirty goods in exports from many poor developing countries rose. See Table 1, p. 1219.}
At the same time, the share of dirty goods imported from the developing countries increased from 3% to 11%; but their share in clean good imports only increased from 9% to 13% over this same period. Similarly, New Zealand’s exports of dirty goods to developing countries fell from 59% of exports to only 46%, while its exports of clean goods rose.\textsuperscript{48}

Similar results are presented in Lucas et al. (1992). They examine the toxic intensity of manufacturing output and GDP for over 80 countries during the 1960-1988 period. They note that while toxic releases per unit of GDP fall as countries within their sample become richer, this only occurs because the composition of output in richer countries becomes cleaner. Coupling this with a finding that the greatest toxic intensity growth occurred in the poorest countries, leads the authors to conclude that all of their results are consistent with the view that “stricter regulation of pollution-intensive production in the OECD countries has led to significant locational displacement, with consequent acceleration of industrial pollution intensity in developing countries”.\textsuperscript{49}

Birdsall et al. (1992) in a study of pollution havens in Latin America reaches similar conclusions. They state “our evidence is strongly consistent with the displacement hypothesis: Pollution intensity grew more rapidly in Latin America as a whole after OECD environmental regulation became stricter” (p. 167). Finally, in one of the most carefully constructed of these studies Mani et al. (1997) examine the production and consumption of dirty goods for several developing country regions plus Europe, North America and Japan over the 1965-1995 period. Their conclusions are more tentative than most, but they note:

“Our cross-country evidence has found a pattern of evidence which does seem consistent with the pollution haven story. Pollution-intensive output as a percentage of total manufacturing has fallen consistently in the OECD and risen steadily in the developing world. Moreover, the periods of rapid increase in net exports of pollution-intensive products from developing countries coincided with periods of rapid increase in the cost of pollution abatement in the OECD economies”, p28.

\textsuperscript{48} See Ratnayake (1998), Tables 1 and 2, p82.
\textsuperscript{49} See Lucas et al. (1992, p80).
The trends these authors identify are not really at issue, but the inferences drawn from them are. To underscore this point, we make use of the models from section 4.1. We first show how the evidence presented above is consistent with a pollution haven story of tightening environmental standards in the North and migration of dirty industries to pollution havens in the South. We then consider an alternative explanation of the same evidence.

In Figure 10 we present a two-region North-South model. In the top panel we depict North’s and South’s relative supply curves. The output of dirty goods relative to clean goods is on the horizontal axis, and the relative price of dirty goods is on the vertical axis. We treat environmental policy as exogenous for simplicity and we have assumed environmental policy is weaker in the South than in the North. In the bottom panel we draw the world relative supply and world relative demand curves that determine the equilibrium relative price of dirty goods.

Consider a tightening of Northern environmental policy. This shifts North’s relative supply to the left from $RS$ to $RS^1$. World relative supply also shifts back to $RS^W$, causing the equilibrium relative price of dirty goods to rises from $p^0$ to $p^1$. As shown in the top panel, the North now specializes less in dirty goods since $N^1 < N$; conversely, the South specializes more in dirty goods since $S^1 > S$. Consequently, a tightening of Northern policy creates dirty industry migration and pollution-haven-driven trade. This result roughly mimics the trends found by many authors in this branch of the empirical literature.

While the evidence discussed above is consistent with the pollution haven hypothesis, alternative explanations are possible. The most direct of these would be Southern economic development fueled by rapid capital accumulation. Consider a factor endowments view of world trade in dirty goods with only slowly changing or static environmental regulations. This alternative scenario is presented in the two panels of Figure 11 below.

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50 Similar results with fully endogenous policy obtain as long as the South’s policy response arising from economic growth is not too strong.

51 Many authors note that the data cannot be explained by differences in regulation alone, and it is therefore surprising that no one has offered a serious alternative based on capital accumulation in the South.
Figure 10

Dirty Industry Migration
In the top panel we again depict North's and South's relative supply curves. We assume that North is capital abundant and has a comparative advantage in the dirty industry. The initial world equilibrium is shown in the bottom panel at A with a price $p^0$.

Now consider the impact of an increase in South's capital stock. Since capital accumulation favors the dirty industry, South's relative supply curve shifts outwards from $RS^*$ to $RS^{**}$. World relative supply shifts out as well from $RS^W$ to $RS^{W1}$. The world price of dirty goods falls from $p^0$ to $p^1$ with the new equilibrium at point B in the bottom panel. We note, using the top panel, that the North specializes less in dirty goods since $N^1 < N$ while the South specializes more in dirty goods since $S^1 > S$. Therefore, capital accumulation in the South implies a development path concentrating on capital-intensive dirty industries. Heightened competition in world markets caused by Southern development leads the North to shift out of these sectors, thereby concentrating on relatively clean manufactures. As a result, Figure 11 roughly mimics the trends reported by many authors – although the reasons for these trends are entirely different. Rather than finding dirty industry migration and pollution haven driven trade, these studies may have instead found Southern economic development!

To disentangle these two possible explanations researchers could adapt the theoretical framework set out in Section 2 to sort out the competing effects theoretically and proceed to empirical testing. Current work has however neglected the possibility of differential rates of factor accumulation across North and South to focus almost exclusively on the role of income.

To see why this hypothesis is worthwhile pursuing, we offer three pieces of evidence. The first is contained in Table 2 below, which should be mandatory viewing for all researchers working in this area. The table lists for 1988, the world’s top 25 dirty good exporters, their production of dirty goods, and the share of their exports arising from dirty good industries. The definition of a dirty good here is very similar, but not identical to that given in Table 1.

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52 We only need that Southern growth be biased towards the dirty sector, while Northern growth is either slower or not biased in this direction.
53 Since the data exhibits two-way trade in both dirty and clean goods, our competitive dirty and clean industries could be replaced by monopolistically competitive sectors with identical firms.
54 Mani et al. (1997) examine trends in domestic factor prices as a possible cause for changes in dirty good output in the developed world, but our analysis here points to changes in factors of production in developing countries as the primary cause.
Figure 11

Southern Economic Development
There are three features of note in this table. The first is simply that the largest producers of dirty goods are rich, OECD countries. In fact, Low et al. (1992) report that over 90% of all dirty good production in 1988 was in OECD countries. This fact alone should tell us that the location of dirty good production across the globe reflects much more than weak environmental regulations. The second feature of note is that even correcting for economic size and focusing on the third column representing the extent to which countries’ exports are specialized in dirty goods, the largest entries in this column come not from desperately poor, unregulated economies, but instead from natural resource rich economies. In some cases, these countries are relatively poor - as is the case for Venezuela and Brazil - but in many they are not; for example, Finland, Canada and Norway have exports heavily reliant on dirty goods. The abundance of natural resources is a far better predictor of specialization in dirty goods than is low income.

The last feature to note is that after excluding countries known to be natural resource rich, the less developed countries making this list are some of the fast growing success stories of the last 2 decades (Korea, Taiwan, Singapore, P.R. China). This suggests that rapid economic development, capital accumulation, and growth are far better predictors of dirty good production than are the absence of environmental regulations.

A second piece of evidence is presented in Figure 12 below. From Figures 10 and 11, it is apparent that one major difference across the explanations is the prediction for the world price of dirty goods. The price of dirty goods rises if a tightening of Northern regulation causes dirty industry migration, but falls if Southern economic development is responsible. As evidence on this score, we present in Figure 12 the relative price of the five dirty industry composites over the period 1965-2000. For ease of reading, (real) producer price indices are normalized to unity in 1965.\textsuperscript{55}

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\textsuperscript{55} The producer price series for each 3-digit SIC industry are annual averages available from the Bureau of Labor Statistics website \url{http://stats.bls.gov}. These are then deflated by the GDP price deflators from the U.S. Department of Commerce, BEA at \url{http://www.bea.doc.gov} to render the price measured in terms of real US 1982 dollars.
Table 2
The Twenty-five Largest Exporters of Environmentally Dirty Goods in 1988

<table>
<thead>
<tr>
<th>Rank</th>
<th>Exporting County</th>
<th>Value ($mill.)</th>
<th>World trade share (%)</th>
<th>Share in country exports (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Germany, Federal Republic</td>
<td>45.6</td>
<td>11.9</td>
<td>15.8</td>
</tr>
<tr>
<td>2</td>
<td>United States</td>
<td>28.5</td>
<td>7.4</td>
<td>10.5</td>
</tr>
<tr>
<td>3</td>
<td>Canada</td>
<td>25.2</td>
<td>6.6</td>
<td>23.8</td>
</tr>
<tr>
<td>4</td>
<td>France</td>
<td>22</td>
<td>5.7</td>
<td>14.6</td>
</tr>
<tr>
<td>5</td>
<td>Belgium-Luxembourg</td>
<td>20.8</td>
<td>5.4</td>
<td>23.5</td>
</tr>
<tr>
<td>6</td>
<td>Netherlands</td>
<td>20.3</td>
<td>5.3</td>
<td>20.2</td>
</tr>
<tr>
<td>7</td>
<td>Japan</td>
<td>18.9</td>
<td>4.9</td>
<td>8.1</td>
</tr>
<tr>
<td>8</td>
<td>United Kingdom</td>
<td>17.3</td>
<td>4.5</td>
<td>14.1</td>
</tr>
<tr>
<td>9</td>
<td>Italy</td>
<td>16</td>
<td>4.2</td>
<td>13.8</td>
</tr>
<tr>
<td>10</td>
<td>Sweden</td>
<td>15.3</td>
<td>4</td>
<td>33</td>
</tr>
<tr>
<td>11</td>
<td>Finland</td>
<td>10</td>
<td>2.6</td>
<td>52.3</td>
</tr>
<tr>
<td>12</td>
<td>Soviet Union</td>
<td>8.3</td>
<td>2.2</td>
<td>29</td>
</tr>
<tr>
<td>13</td>
<td>Brazil</td>
<td>7.9</td>
<td>2.1</td>
<td>24.3</td>
</tr>
<tr>
<td>14</td>
<td>Austria</td>
<td>6.9</td>
<td>1.8</td>
<td>24.6</td>
</tr>
<tr>
<td>15</td>
<td>Spain</td>
<td>6.8</td>
<td>1.8</td>
<td>18.4</td>
</tr>
<tr>
<td>16</td>
<td>Korea, Rep. Of</td>
<td>6.6</td>
<td>1.7</td>
<td>11.8</td>
</tr>
<tr>
<td>17</td>
<td>Taiwan, China</td>
<td>6.2</td>
<td>1.6</td>
<td>10</td>
</tr>
<tr>
<td>18</td>
<td>Norway</td>
<td>6</td>
<td>1.6</td>
<td>27.3</td>
</tr>
<tr>
<td>19</td>
<td>Australia</td>
<td>5.7</td>
<td>1.5</td>
<td>19.8</td>
</tr>
<tr>
<td>20</td>
<td>Switzerland</td>
<td>5.6</td>
<td>1.5</td>
<td>11.2</td>
</tr>
<tr>
<td>21</td>
<td>China, People Rep.</td>
<td>5.2</td>
<td>1.4</td>
<td>9.6</td>
</tr>
<tr>
<td>22</td>
<td>Rep. Of South Africa</td>
<td>5</td>
<td>1.3</td>
<td>41</td>
</tr>
<tr>
<td>23</td>
<td>Singapore</td>
<td>4.8</td>
<td>1.3</td>
<td>19.2</td>
</tr>
<tr>
<td>24</td>
<td>Venezuela</td>
<td>4.3</td>
<td>1.1</td>
<td>49.7</td>
</tr>
<tr>
<td>25</td>
<td>Saudi Arabia</td>
<td>4.1</td>
<td>1.1</td>
<td>14.9</td>
</tr>
</tbody>
</table>

Source: Low et al. (1992, p95)
The figure clearly shows no strong upward trend in dirty good prices over this period as would be predicted if a tightening of Northern pollution regulations drove trade. In fact, with the exception of Pulp and Paper, all of the real producer price indices are either flat (as is the case for Industrial Chemicals and Non-metallic Minerals) or declining as illustrated by both Iron and Steel and Non-ferrous metals. While other explanations can be found for these trends, on its face these data are inconsistent with the view that tighter regulation in the North drove up costs of production to such an extent that dirty industries had to migrate to less suitable pollution havens in the South.  

The last piece of evidence for an alternative hypothesis is provided by the studies themselves. Several authors report that while their empirical results show all developing countries alter the mix of their production towards dirty goods, more open developing countries have a cleaner mix of industries than their closed counterparts. For example, Birdsall et al. (1992; p. 167) note “The econometric evidence, though at best exploratory, suggests that over the last two decades the more open economies have ended up with a cleaner set of industries”. And Lucas et al. (1992; p. 80) qualify their results on the pollution havens by stating “Pollution intensity has grown most rapidly in developing countries which are relatively closed to world market forces….The opposite seems to have been true, however, for more open economies”. These findings are, however not a qualification to the pollution haven hypothesis – they are in direct contradiction to the pollution haven hypothesis.

To see why, note that under the pollution haven hypothesis South has a comparative advantage in dirty goods. Therefore import substitution policies by Southern countries would lower the share of dirty goods in Southern production and not raise it. Under the pollution haven hypothesis, relatively closed Southern countries should have a cleaner mix of industries; it is, after all, trade that is making them dirtier!

Alternatively, under the alternative Southern economic development scenario these results have a natural explanation. In this view, North has a natural comparative advantage in

56 Technological progress is a possible explanation, but note since these are real prices we need to assume the rate of technological progress in dirty industries was greater than that in all of manufacturing. This is a harder case to sell. Changes in the demand for these products as income’s rise is also a possibility.
Figure 12 Trend in Dirty Good Prices

- Paper and Pulp (26)
- Industrial Chemicals (28)
- Nonmetallic Mineral Products (29)
- Iron and Steel (332)
- Nonferrous Metals (336)
dirty goods. North’s dirty good exports have fallen over time as South industrializes. In this context, import substitution policies by Southern countries raise the share of dirty goods in Southern production. Therefore, under the factor endowment cum economic development explanation closed南方 economies should be relatively dirtier than their open counterparts. This is consistent with the empirical findings.

While our analysis of the role of Southern capital accumulation in explaining the evidence is only suggestive, our point is that there are reasonable alternatives to the simple pollution haven hypothesis that need to be considered when interpreting the evidence.

Summary

While it is very easy to dismiss this branch of the empirical literature because the data used is constructed, we think this approach has some merit. Given the difficulty in obtaining pollution data for a broad cross-section of countries, it seems reasonable to proceed with further analysis along these lines.

However, future research must proceed carefully. For example, it would be useful to be more precise concerning the types of measurement error introduced by the classification of industries into dirty and clean. What assumptions are we making concerning this error? Is it correlated across time, countries, industries?

As well, future analysis must rely more heavily on theory to suggest alternative hypotheses and discipline inferences from the available data. In particular, we would suggest an investigation of the role of factor accumulation in determining the pollution intensity of national output. The search for pollution havens in the data has obscured the role capital accumulation and natural resources must play in determining dirty industry migration and trade.

Environmental Stringency and International Competitiveness

This second branch of empirical literature addresses our criticisms above: it proceeds from a well-known theoretical framework, and admits determinants other than income levels to shape comparative advantage in dirty goods. The majority of these studies adopt a methodology linking the cross-sectional variation in trade flows to industry characteristics. Industry
characteristics are described both by conventional measures of comparative advantage (factor costs, trade barriers, and perhaps proxies for technology differences) and a measure of environmental stringency (typically the industry wide share of pollution abatement costs in value-added). Grossman and Krueger (1993) adopted this method in their NAFTA study. Recent contributions include Osang et al. (2000), Levinson et al. (2001), and Ederington et al. (2001). A few studies relate cross-country variation in the exports of a single (composite) commodity to national measures of factor endowments and environmental stringency. Tobey (1990) is the best-known study of this type.

In either case the Heckscher-Ohlin-Samuelson (HOS) model of international trade motivates the theory, and the methods link cross-sectional measures of trade performance to cross-sectional variation in the stringency of regulation.

While this branch of the empirical literature is a step forward, its advances come at some cost. The first is an almost exclusive focus on trade flows into and out of the U.S. This is natural because only the U.S. has readily available data on pollution abatement cost expenditures by firms. The lack of cross-country variation makes any inference about the pollution haven hypothesis rather indirect. Rather than looking for pollution havens directly, this literature examines the relationship between pollution abatement costs (or other measures of stringency) and trade flows. If changes in pollution regulations have only modest effects on trade flows, then it becomes difficult to maintain the pollution haven hypothesis.

A second problem arises from the cross-sectional approach taken in this literature. These studies link the cross–sectional variation in trade flows to industry specific measures of factor and regulatory costs. But cross-sectional estimation is especially sensitive to the exclusion of unobservable industry characteristics. Unlike the literature discussed in the last section, investigators here do not have access to a panel of data; hence panel data techniques accounting

57 A related literature tries to link the stringency of standards with foreign direct investment or plant location. For a review of this literature see Levinson (1996).
58 Tobey (1990) is perhaps the best example.
59 Recently, data from Canada, the U.K. and Australia is now available although the definitions of costs, industry coverage, etc. are somewhat country specific. As well, Tobey (1990) employs an UNCTAD qualitative indicator of environmental stringency available for many countries.
for unobservable variables are not available. As a result, we suspect that many of the results in this literature reflect the influence of unmeasured industry characteristics.

Finally, this literature inherits the weaknesses of its predecessor. It builds on an earlier literature in trade theory, started by Baldwin (1971), linking variation in industry characteristics to trade performance measures such as gross or net exports. A small debate in trade theory arose over the theoretical justification for these regressions. At one level, the debate is settled: under the standard HOS assumptions, the estimated coefficients on factor cost shares do not measure or reveal factor abundance except under quite stringent assumptions regarding technology. But at an empirical level, the verdict is far less clear. While it is difficult to motivate the cross-sectional work formally, the conclusions drawn from it accord well with estimates found using "more

We have nothing to add to this debate, and none of our criticisms of the literature flow from it. An interested reader should refer to Leamer and Levinsohn (1995) for further discussion.

**Environmental Stringency and Competitiveness**

A typical study in this literature employs U.S. data on the cross-sectional pattern of trade in manufactures together with data on factor shares and pollution abatement costs. The standard study would estimate the following equation:

\[
T_{it} = \beta_0 + \beta_1 S_{it} + X' \beta + \mu_{it}
\] (4.9)

where \( T_{it} \) is a measure of trade flows in industry “i” in year t such as the value of net exports, \( S_{it} \) is an industry specific measure of environmental stringency, and \( X \) is a matrix of other controls which differ across studies. These controls are typically the cost shares of labor (sometimes disaggregated by skill class), the cost share of capital, and in some cases tariff rates. The set of industries studied is often the entire US manufacturing sector, but sometimes the analysis is limited to the set of manufacturing industries that are most pollution intensive.

The measure of trade flows, \( T_{it} \), differs across studies. Since the underlying model motivating the equation is the HOS model, net exports is the most comfortable choice. Since

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60 See for example Bowen et al. (1992).
industries differ in scale so dramatically, most authors scale the dependent variable by industry shipments, value-added, or domestic consumption. The measure of environmental stringency is pollution abatement costs divided by industry value-added. This series is available for both capital and operating costs for all of US manufacturing going back to the early 1970s. Most authors employ the operating cost series.

The almost universal finding in this literature is that the stringency of pollution regulations does not matter to trade flows with coefficients on the stringency variable being small and often insignificant. In some studies, the coefficient’s sign is found to be counterintuitive, suggesting a positive relationship between tighter regulation and net (or gross) exports. This awkward sign on the pollution abatement cost variable has not led to a wholesale re-examination of the estimation methodology, but instead is often cited as evidence in favor of the Porter hypothesis (see Porter and van der Linde (1995)). Porter et al. argue that tighter environmental regulation spurs technological innovation, and hence tighter regulation could, in theory, raise exports or lower imports.  

Despite the sometimes-troubling sign on the pollution abatement cost variable, the inference drawn from these studies is that there is little connection between the stringency of environmental regulation and trade flows. The explanations for this finding varies, but most often include the fact that pollution abatement costs are only a small fraction of total costs. And hence a reader of this literature is led to conclude much as Tobey (1990) did over a decade ago:

“It is found that the stringent environmental regulations imposed on industries in the late 1960s and 1970s by most industrialized countries have not measurably affected international trade patterns in the most polluting industries” p.192

While it is possible that Tobey’s original conclusion may be correct, there are several reasons to remain skeptical. In our view, Tobey’s own analysis does not support it, and our

61 They state “in this paper, we will argue that properly designed environmental standards can trigger innovation that may partially or more than fully offset the costs of complying with them. Such “innovation is often coincident with improving the productivity with which resources are used” p 98. An entirely different view of regulation’s effect on productivity is presented in Gray (1987).
reading of the evidence suggests unmeasured industry attributes and endogeneity problems are at least partially responsible for the inconclusive results.

Before we proceed to discuss the bulk of the literature in this area, we review Tobey’s contribution given its prominence in the literature and its slightly different method.

**Tobey’s Analysis**

Tobey’s analysis differed from the methods described above in two significant ways. First, he related cross-country variation in the exports of 5 dirty commodity groups to country-specific measures of factor endowments and environmental stringency for a group of 23 countries. Therefore, in terms of equation (4.9), the “i” subscript refers to countries, the matrix X contains measures of national factor endowments (and not cost shares), and $S_i$ is an ordinal measure of environmental stringency (not pollution abatement costs).

In all the regressions reported, Tobey finds the environmental stringency variable to be an insignificant determinant of net export flows. Moreover, in a follow-up omitted variable test conducted with a larger cross-section of countries, Tobey was not able to reject the hypothesis that environmental stringency had no effect on net exports. On the basis of these results, Tobey presented the conclusion cited above.

A close read of Tobey’s contribution reveals several concerns. His main results follow a series of 5 cross-country regressions, one for each commodity group. Each of these regressions has only 10 degrees of freedom. Not surprisingly then, the vast majority of the coefficients estimated are insignificant.\(^{62}\) While the stringency variables are insignificant, so too are 55 of the 65 coefficients estimated. In fact, most of the factor endowments are insignificant most of the time. Only 1 of the 12 included factor endowments is significant in 3 commodity groups (capital); and only 1 other is significant in more than 1 commodity groups (a specific variant of land). Therefore, insignificance is the norm in these regressions.

We note also that he employed an UNCTAD ordinal measure of environmental stringency as an explanatory variable. Rather than represent the ordinal measure as a series of

\(^{62}\) Student’s t for a two-sided test is 2.22 at the 5% level when there are 10 d.f. We will adopt this level as representing statistically significant.
dummy variables, which would impose no additional assumptions on his estimation, Tobey enters a score from this measure directly in the regression. Consequently, he implicitly turns an ordinal measure into a cardinal one. Therefore his results are conditional on the functional form employed in this transformation. If we adopt a different transformation, we can in many cases change both the sign and significance level of the transformed variable.63

An additional concern is that his cross-country analysis does not allow for any degree of heterogeneity across countries. His analysis assumes all countries in his sample of 23 share an identical mapping from endowments to trade; therefore assuming Liberia, Nigeria and Colombia share technologies and market institutions with the U.S., Japan, Sweden, Germany and Norway.64,65

Therefore, while Tobey’s analysis is perhaps the most cited study arguing against a link between environmental stringency and trade flows, its conclusions rest on tenuous foundations.

**Unobserved Industry Characteristics**

The bulk of the literature following Tobey dealt with some of the problems raised above, but on balance comes to a similar conclusion. However, we think that a more fundamental

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63 See for example the methods discussed by Yitzhaki (1990).

64 A related concern is that the dependent variable is not scaled to account for country size. Scaling is routinely done because country size, which is undoubtedly correlated with the right hand side endowments, will also be correlated with any unmeasured elements in the error term.

65 Further concern follows from an examination of his omitted variable test. Tobey expands his collection of countries from 23 to 58, and excludes environmental stringency as a regressor in his cross-country regressions. He then divides his sample of countries into three groups according to development level and compares the proportion of positive and negative residuals from his net export regressions within each development group. Tobey is unable to reject the null hypothesis of identical proportions of errors; therefore, excluding environmental stringency does not lead us to over-predict or under-predict net exports in a systematic way across country groupings. But this omitted test is that it relies on the assumption that the omitted variable (environmental stringency) is orthogonal to the set of included regressors (Tobey (1990, p199, assumption A1)). This requires that (unmeasured) pollution regulations be orthogonal to all of the country characteristics described by its endowments of capital, land, minerals and oil. But these characteristics determine both a country’s production structure (i.e. its demand for pollution) and its national income (i.e. the supply of pollution). If we really believed the maintained orthogonality assumption, why would we be interested in grouping countries according to development level to conduct such a test?
problem has affected this literature. Our reading of the evidence suggests that the endogeneity of pollution abatement costs, and unmeasured industry characteristics may well be responsible for the results found.

To understand our concerns, consider Figure 13, which illustrates the logic behind the methodology in this literature.

[insert Figure 13 here]

In the top panel we depict a pollution demand and supply curve from our model of section 2. In the bottom panel we depict an import demand curve for the dirty good as a function of world prices and the equilibrium level of pollution (all other determinants are suppressed). As drawn, a higher level of pollution raises dirty good output and shifts the import demand curve inwards; i.e. $Z^1 < Z^0 < Z^2$, as shown in the top panel.

The existing literature links pollution abatement costs to imports, conditional on conventional factor endowments, which in turn determine factor costs. We can illustrate the typical inference by starting at point A in both the top and bottom panel. At A, pollution is $Z^0$, imports $M^0$, and the initial pollution tax $\tau^0$.

Now consider an exogenous change in pollution regulations – here modeled as taxes - from $\tau_0$ to $\tau_1$. Since taxes are assumed to be set exogenously in this framework, pollution supply is, at this point, irrelevant to the analysis. Seeking to avoid the tax, firms abate more intensively and abatement costs as a fraction of value-added rises. Pollution falls to $z_1$ along the given pollution demand curve $D^0$.

In the lower panel, we identify the trade consequences of this exogenous policy change. The fall in pollution to $z_1$ shifts the import demand curve outwards as less of the dirty good is produced. Imports rise to $M_1$ and a positive relationship between the stringency of regulation, pollution abatement costs, and imports is established. Alternatively, if we assumed our small country exported the dirty goods we would have found tighter regulation lowering net exports in this industry.

66 Alternatively you can interpret the existing literature as assuming all variation in pollution arises from shifts in pollution supply holding pollution demand constant.
Figure 13

Imports and Pollution Regulation
The key feature of this analysis is that pollution falls along a given pollution demand curve as policy becomes more stringent. But more stringent policy also raises the incentive to abate more intensively, while the lower pollution level drives up imports. Hence after controlling for other more conventional determinants, affecting the location of import demand, variation in pollution abatement costs can be linked with import penetration.

There are at least two ways this logic can break down. Here we will introduce an unobservable industry attribute that affects both pollution taxes and imports. To do so, pollution taxes must be set endogenously. Therefore, now assume the pollution supply and demand framework set out in the top panel determines pollution taxes. Then the equilibrium is given by the intersection of pollution demand and supply at A. The level of pollution taxes is $\tau_0$ and the equilibrium level of pollution is $z_0$.

Now consider an increase in industry size (created for example by technological progress favoring the one industry shown). In the top panel, pollution demand shifts right from a scale and composition effect.\(^\text{67}\) Then pollution rises to $z_2$ as shown, while the pollution tax rises as before to $\tau_1$. Pollution abatement costs rise as before.

In the lower panel, industry growth shifts the dirty good import demand inwards and imports fall to $M^2$. Imports fall because technological progress raises domestic output and because of the complementary change in pollution levels. Even accounting for the direct impact of technological progress, we now find a negative correlation between imports of dirty goods and pollution abatement costs.

Therefore an unmeasured industry characteristic that shifts pollution demand rightwards and lowers imports will confound typical estimates. We have illustrated this potential problem by assuming that industry-specific growth creates co-movements in pollution abatement costs and imports. But many other determinants could work as well.

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\(^\text{67}\) In general, pollution supply shifts left as well, creating a technique effect that dampens the increase in pollution. To avoid clutter, we ignore the technique effect. Unless the income elasticity is large, this does not qualitatively affect the result (since an increase in capital raises pollution unless the elasticity of marginal damage is in excess of one). To avoid clutter we have set the elasticity to zero.
For example, suppose pollution intensive goods have higher than average transport costs (the cement industry comes to mind). Then the domestic dirty good industry has natural protection from imports. Transport costs shift pollution demand rightwards because the domestic price now exceeds the world price for the imported good. As well, a higher delivered price domestically lowers imports. If we fail to include transport costs in our estimation, then our cross-sectional results will again be tainted. If transport costs are higher in pollution intensive industries, we may find pollution abatement costs negatively related to imports.

Alternatively, suppose pollution intensive industries are natural resource intensive. This is surely true for many of the dirtiest industries in manufacturing as evidenced by Table 2.1.\textsuperscript{68} Since natural resource intensity is not accounted for in the analyses, we are again missing a shift right in pollution demand – because natural resources are a complementary factor - and a shift left in import demand – because domestic production is higher than would be predicted on the basis of conventional factor endowments. As a result, our estimations may again reveal a negative relationship between pollution abatement costs and imports.

Each of the examples given above suggests a problem arising from unmeasured determinants of both pollution demand and imports. The unmeasured characteristics are industry size, transport costs or natural resource intensity.

**Policy Linkage: Political economy and Market power motivations**

A related problem arises if trade and environmental policy are linked via the government’s policy process. In this case, import penetration and pollution abatement costs are determined simultaneously. Antweiler et al. (2001) discuss two possible links between trade and environmental policy. The first arises when a government is politically motivated. The second arise when the economy is large and has the ability to manipulate world markets by altering

\textsuperscript{68} Further evidence on this score is provided in Robison (1985) who calculates the direct plus indirect pollution abatement costs embodied in 1$ of output for 20 2-digit sectors in the United States in 1977. On this metric, the top six dirtiest sectors are Electric Utilities (5.4%), Agricultural Fertilizers (2.5%), Copper (2.4%), Ferrous metals (2.2%), Paper (2.0%), and other Non-Ferrous metals (1.8%). See Table 1, p. 704.
pollution policy. In principle both could be present simultaneously, but it is simpler to discuss them in turn.

Suppose factors specific to polluting industries are hurt by trade liberalization.\(^69\) Then a politically motivated government may be tempted to compensate these factors for the injury felt. A relaxation of environmental regulation could be partial compensation. This political economy motivation then predicts that a tariff reduction on dirty good imports that shifts import demand outwards, calls forth a compensating relation in pollution policy that shifts pollution supply outwards. As a consequence, imports rise by less than expected, pollution abatement costs are lower than expected, and the correlation between pollution abatement costs and imports is weakened.\(^70\) Alternatively if our country is a dirty good exporter, then a tariff cut on clean good imports harms the factors specific to the clean good industry. To compensate specific factors in the clean industry, pollution supply shifts back, while domestic production of the clean good rises.

In both cases, the additional political economy elements lower pollution abatement costs when imports rise, and raise pollution abatement costs when exports rise. Consequently, these actions make the typical “competitiveness” connection between higher pollution abatement costs and reduced exports, weaker. If we are unaware of these possibilities, we may incorrectly infer that a change in pollution regulations has no effect on trade flows.\(^71\)

A similar set of events can occur in a large open economy. Consider a dirty good importer and assume a negotiated tariff reduction has taken place. The direct effect of this tariff reduction is a shift right in import demand and an import surge; but our large open economy has an incentive to lower the import surge by relaxing its pollution regulations. In this way, the government is substituting environmental policy for trade policy. This relaxation shifts pollution supply to the right, raises pollution and raises domestic production of the dirty good. Greater

\(^{69}\) Alternatively, factors used intensively in the dirty industry. The specific factors terminology here seems more natural.

\(^{70}\) Eliste et al. (1999) find increases in the stringency of regulation offset to some extent by an increased value of government transfers (including tariffs). This evidence is consistent with the political economy motivations discussed here.

\(^{71}\) Van de Beers (1997) interpret their finding that tighter home country regulation lowers imports as suggesting a political economy link between tariffs and environmental regulation.
domestic production in turn reduces the negative terms of trade effect the tariff cut would have engendered. A similar effect works for a dirty good exporter.

Again we find that a policy linkage leads governments to lower pollution taxes when imports rise, and raise pollution taxes when exports rise. Consequently, if these tariff-substitution effects are present in the data, it will be difficult to identify any direct competitiveness effect arising from tighter regulation.

While the analysis above may be suggestive of potential problems, it is not proof of them. A review of the empirical literature however, reveals ample evidence consistent with our concerns. And a review of related literature in both environmental and international economics reveals how similar concerns have proven to be important in the past.

Kalt (1988) finds a positive relationship between net exports and pollution abatement costs, which on its face is directly opposite to what is expected. The relationship however becomes negative once natural resource industries are excluded. This negative effect is further enhanced when one of the dirtiest industries - the chemicals industry - is removed. One explanation for these results is unmeasured industry heterogeneity. If pollution abatement costs are positively related to unmeasured natural resource intensity, and natural resources are a productive factor, then these industries will have larger domestic production. Pooling across industries that vary in their reliance on natural resource intensity could well produce the spurious positive result. Removing these industries leads to the expected result.

As well, if the chemical industry is large and productive, its success may well have created the tighter regulations it faces and enlarged its world market. In our framework, both unmeasured natural resource intensity and industry productivity shift pollution demand rightwards and import demand leftwards obscuring the simple higher PACE lower import link. 72

Grossman and Krueger (1993) also report counter-intuitive signs for their pollution abatement cost variable in four of the six cross-industry regressions explaining U.S. imports from Mexico. In only two of these cases is the negative relationship statistically significant at the 5%

72 Osang et al. (2000) employ both industry and time fixed effects which makes it more difficult to attribute their results to unobserved (constant) industry attributes. The endogeneity of regulation could however still be responsible for the results.
level. Nevertheless, the results are troubling and the authors themselves note the strange sign on this cost variable may be arising from omitted variable bias.

Further support for our interpretation is evident in related literatures. For example, consider Daniel Trefler’s well-known (1993) empirical paper on endogenous trade protection. Trefler notes that empirical research had found only an embarrassingly small impact of tariff reductions on trade flows. He suggests it arises from the literature’s treatment of trade barriers as exogenous. Trefler adopts a cross-sectional regression framework quite similar to that discussed above and estimates a standard one-equation model treating import barriers as if they were exogenous. He finds non-tariff barriers have a small negative effect on imports. When non-tariff barriers are treated as endogenous, the results are striking: Trefler’s estimate for the impact of trade restrictions on imports is 10 times higher.\textsuperscript{73}

Related evidence is presented in Levinson (1998, 1999) who examines the relationship between state-to-state hazardous waste shipments and import taxes on hazardous waste. Levinson regresses state-to-state waste shipments on state characteristics, distances and wastes tax rates. With no correction for endogeneity or unobserved heterogeneity, he finds a positive and statistically significant relationship between import taxes and imports of disposal waste. Once he accounts for the potential endogeneity, he finds a strongly negative and significant relationship. Higher waste taxes deter imports of hazardous waste.

These two studies show how endogeneity and unobserved characteristics can lead entire literatures astray. Given the wide variance in results reviewed here, it is likely that similar problems abound. Two recent studies have started to make some progress on this front. Levinson et al. (2001) present a simple model with endogenous pollution policy to suggest an empirical strategy testing for the impact of regulations on trade flows. They identify industry size, natural resource intensity, political economy concerns, and tariff substitution as likely candidates creating a link between regulation and imports. They then estimate a two-equation model adopting a methodology similar to Trefler (1993). The results are similarly striking. In the cross-section regressions with no correction for endogeneity there is little relationship

\textsuperscript{73} See Table 5, page 150 column 1.
between net exports and pollution abatement control expenditures; however once they instrument for pollution abatement costs, the results change dramatically. Tighter pollution regulations lower net exports significantly.

Similarly, Ederington and Minier (1999) examine the link between pollution abatement costs and imports in a setting where imports and control costs are determined simultaneously. They motivate their work on the basis of tariff-substitution as outlined above. In their fixed-effects implementation they find a small, but statistically significant relationship between pollution control costs and imports. A 1% point change in costs, raises import penetration by 1.2% points. In contrast, their 3SLS estimates yields an unbelievably large impact, with a 1% point increase in pollution abatement costs raising import penetration by 15% points. This result is, however, dependent on the authors’ instrument choice and excluding exports as an instrument for imports yields an estimate very close to the fixed effects implementation. Further work along these lines is certainly required.

**Industry Selection**

There is one last caveat we wish to discuss. It is common in this branch of the literature to select only the dirtiest industries for study. Therefore, in some studies all industries with pollution abatement costs greater than x% are examined, in others it is only the dirtiest by emission intensity figures, etc. For example, Tobey (1990) examines trade in 24, 3 digit SIC industries for which pollution abatement costs in the U.S. exceeded 1.85% of total costs. Similarly, Xu (1999) concentrates on 134 environmentally sensitive commodities grouped within a set of three digit industries chosen because pollution abatement costs exceed 1%. Low and Yeats (1992) follow a similar procedure.

The logic behind this procedure is two-fold. By narrowing the field of inquiry researchers can focus more intensively on the industries selected. And secondly, researchers often argue that if we are to find the impact of pollution regulations on trade flows anywhere, it should be within the set of industries where these costs are “significant”. At first blush this seems reasonable. But a possible concern is that these dirty industries share unobservable characteristics
making them less and not more likely to relocate. By selecting only the dirtiest, we may have unwittingly also selected the least mobile.\textsuperscript{74}

Many of the industries identified as pollution intensive industries are also natural resource intensive. Their location is tied to specific factors such as coal, trees, oil or mineral deposits to a far greater extent than is a “typical” manufacturing industry. That is, these industries share an attribute – natural resource intensity – known to inhibit mobility. For example, Van Beers (1997) presents a list of the top 14 dirtiest industries on the basis of pollution abatement expenditures, and finds 10 of these to be resource-based products. Only Iron and Steel, Metals Manufactures, Chemical Materials, and Cement are not classified as resource based. This industry selection problem appears to have some bite. For example, Van Beers (1997) finds no significant relationship between the strictness of regulation and exports of dirty goods. But when he examines the subset of industries that are both “dirty” but not resource-based, he finds a significant negative relationship between the stringency of regulation and exports.\textsuperscript{75}

Summary

Controlling for conventional determinants of comparative advantage is necessary if we are to isolate the impact of pollution regulations on trade flows. While evidence from this branch of the literature cannot prove or disprove the pollution haven hypothesis, evidence on the impact of regulation would be useful to our weighing of the pollution haven and factor endowments hypotheses.

The literature has shown that conventional factor endowment determinants influence dirty good trade, but the conclusion that pollution regulations have little effect on trade flows is

\textsuperscript{74} For example, suppose we were asked to investigate the impact of longer prison sentences on criminal behavior and we choose a set of hardened criminals as our sample. After all, hardened criminals have had much experience with both crime and incarceration. Would we be surprised to find little deterrent effect on their behavior? The answer is clearly no. The reason is that there are unobservable attributes common to all hardened criminals but uncommon in the entire population, that make their supply of criminal behavior very inelastic. The logic and potential problem is the same here.

\textsuperscript{75} Van de Beers (1997) evidence on other scores is less convincing. They find for instance that tighter regulation in the home country lowers imports into the country. They suggest that unmeasured trade barriers are positively correlated with regulation and this political economy link is responsible for the result.
premature. Tobey’s (1990) original evidence is extremely weak, and the subsequent literature appears to suffer from problems arising from endogeneity and unobservable characteristics. We should be wary of a hasty conclusion that pollution regulations do not matter, especially given the history of related work in both trade and environmental economics. If we are correct in attributing the weak results to estimation problems, then there is much to be gained by adapting the methods of Trefler and Levinson to this issue.

We suspect that once further work has investigated these possibilities, a role for pollution abatement costs in shaping comparative advantage will appear. How large a role this may be is, as yet, unknown. Reported costs for pollution abatement have however been climbing quite rapidly over the last twenty years. For example, in 1984 pollution abatement capital expenditures represented only 2.8% of new capital expenditures in all U.S. manufacturing industries, but by 1993 this share had risen to 7.0%. In certain industries the increases are very large. Unless we are willing to assume that these costly investments are somehow undone by Porter’s “innovation offsets”, or merely reflect problems in survey methods, the growing share of costs attributed to pollution abatement must have some effect on trade flows and perhaps world prices.

Further work along these lines is surely called for, but should address three current deficiencies. First, future research should consider the issues raised by endogeneity and unobserved characteristics more fully. Second, research should be more closely guided by theory. If we are to sort through the roles of unmeasured industry attributes and endogeneity we need more guidance from theory, not less. Finally, researchers should be wary of inferring too much from their estimates. Finding a significant relationship between tighter regulations and trade flows does not constitute a test of the pollution haven hypothesis. More conventional determinants of dirty good trade may well be far more important.

Scale, Composition and Technique Effects

The increase in pollution abatement operating costs is much smaller from .63% of total costs in 1984 to only .79% in 1993. Figures are drawn from Nandy et al. (2000). As well, see the discussion of potential errors in reporting capital expenditures on pollution abatement in Jaffe et al. (1995; p142)
Finally we turn to a group of studies attempting to estimate and then add up the scale, composition and technique effects arising from trade liberalization. Although the notion of scale, composition and technique effects predates Grossman and Krueger, economists didn’t pay much attention to this conceptual breakdown until they employed it to assess the environmental impact of NAFTA.\(^{77}\) As such the GK study was the first to fashion a logical argument along these lines. Their argument was quite direct and powerful.

On the basis of their estimated EKC for sulfur dioxide, Grossman and Krueger concluded that any income gains created by NAFTA would tend to lower pollution in Mexico. This followed since Mexico’s then current per capita income placed them on the declining portion of their estimated hump-shaped EKC. Since the shape of the EKC was taken to reflect the relative strength of scale versus technique effect, Mexico was literally now over the hump. Future income gains would call forth tighter regulation with technique effects now dominating scale effects.

To evaluate the composition effect of trade, Grossman and Krueger relied on both the evidence presented in their cross-sectional regressions and the results from CGE work by Brown, Deardorff and Stern (1991). Recall that the cross-sectional regressions discussed earlier indicated that U.S. comparative advantage was in human and physical capital-intensive industries. Therefore, further trade liberalization via NAFTA should shift Mexican production towards low-skilled, and presumably less pollution intensive, manufactures. While it is difficult to isolate the pollution consequences of this composition effect, Grossman and Krueger note that CGE estimates from Brown et al. (1991) indicate a fall in the demand for electric utilities output in Mexico. This occurs via the industrial restructuring created by the trade liberalization. Since utilities are major polluters – especially with regard to sulfur dioxide - it appears that the composition effect for Mexico was likely to be slightly beneficial to the environment. In contrast, utility output was forecast to rise slightly in both the U.S. and Canada.

These conclusions are altered somewhat if we assume NAFTA spurs capital accumulation in Mexico. For example, Brown et al. present CGE results assuming a NAFTA

inspired 10% increase in Mexico’s capital stock. In this case, while the trade liberalization per se appears to be beneficial to Mexico’s environment, a 10% increase in the capital stock drives up electric utility output by 9%. Apparently, capital-intensive manufactures are energy intensive and this change in Mexico’s factor endowments may raise emissions from utilities.

Similar results obtain when Grossman and Krueger calculate the change in toxic releases implied by the industry reallocations predicted for NAFTA. Again using the CGE output from Brown et al. (1991), trade liberalization alone appears to lower toxic releases in Mexico while it raises them in the U.S. and Canada. If we again assume a NAFTA-induced change in Mexico’s capital stock, then toxic releases rise in Mexico.

In total then, the impact of further trade liberalization Mexico is fairly clear: accounting for scale, composition and technique effects, NAFTA should be good for the Mexican environment. If we add in additional impacts of NAFTA such as accelerated capital accumulation then the picture is less clear.

Despite the limitations mentioned previously, the Grossman-Krueger study was far ahead of existing work in this area. They employed a theoretically based methodology for thinking about the environmental impacts of trade, and presented empirical evidence on these scores. Future research was left to improve on their start and to deal with some of the unanswered questions.

At present however only a handful of studies follow Grossman and Krueger in adding up scale, composition and technique effects. Fewer still make any real headway in evaluating the environmental effects of trade.

Cole (2000) attempts to measure the environmental impact of the Uruguay round trade liberalization by calculating their implied scale, composition and technique effects. His methods mimic Grossman and Krueger’s work closely, and hence while the application is different, no substantial improvement in method is provided.

Dean (1998) estimates the impact of trade and growth on water quality in several Chinese provinces and interprets her results in the context of scale, composition and technique effects. Dean adopts a reduced form model that is a special case of the continuum pollution-haven model presented in Copeland and Taylor (1994). There are two productive factors: emissions and an
aggregate of all other factors; two industries, which differ only in their pollution intensity; emissions are in variable supply; and China is treated as a small open economy with existing trade restrictions. Since industries differ only in their use of emissions, this is a two-sector pollution haven model very similar to that discussed earlier.

Since sectors do not differ in their conventional factor use, Dean is unable to weigh pollution haven motives against more conventional factor endowment determinants. She finds a fall in trade restrictions (proxied by a reduction in the black market premium) raises pollution directly; that is, pollution demand shifts right with trade liberalization. In the context of the model, this suggests China’s low income makes it a pollution haven. But since the fall in trade restrictions also raises income, (and hence would shift pollution supply left) the overall impact on emissions in China is unclear.\footnote{The innovation in Dean’s paper is the direct link she draws between income growth and trade restrictions. But little is said about this link and no formal modeling of the process is given. For example, if the link is the typical efficiency gains small open economies achieve from trade liberalization then it would be necessary in the empirical work to treat these gains as proportional to net trade flows as they represent terms of trade effects. If they occur via other means such as technology transfer or direct productivity effects, then it would be necessary to incorporate them into the model’s implicit abatement production functions. Neither are attempted, nor is there any discussion of the controversial empirical literature linking more open trade policies with economic growth.}

**Is Free Trade Good for the Environment?**

Antweiler, Copeland and Taylor (2001) develop a theoretical model to divide trade's impact on pollution into scale, technique and composition effects and then estimate and add up these effects using data on sulfur dioxide concentrations from the Global Environment Monitoring Project. Both factor endowment and pollution haven motives for trade are allowed for. This research differs from the existing literature in the prominence given to the role of theory in developing and examining the hypotheses, and in the use of a consistent data set to estimate all three effects of trade. Earlier work by Grossman and Krueger recognized the importance of conventional determinants of comparative advantage, but their examination of the composition effect of trade was based on data distinct from that used in estimating their scale and technique.
effects; moreover the evidence they presented was specific to Mexico. In contrast, Antweiler et al. estimate the composition effect jointly with the scale and technique effects on a dataset including over 40 developed and developing countries.

**Pollution haven versus Factor Endowment Motives**

Antweiler et al. estimate a reduced form equation for sulfur dioxide concentrations based on a model much like that developed in the early part of this essay. Among other things, they control for relative factors endowments, scale of production activity, determinants of policy (such as per capita income), and openness to international trade.

Previous studies had looked for the effects of openness by simply adding it as an extra explanatory variable. But both the pollution haven hypothesis and the factor endowment hypothesis predict that openness to trade will alter the composition of national output in a way that depends on a nation’s comparative advantage. Therefore, Antweiler et al. capture trade’s composition effect by interacting a measure of openness with country characteristics determining comparative advantage. Under the pollution haven hypothesis, a country’s income relative to the world average is relevant; under the factor endowments hypothesis, capital abundance relative to world averages is relevant. They adopt a 2nd-order Taylor series approximation for the unknown function relating these determinants to comparative advantage.

This method and logic receives some support in the data. After accounting for variables capturing scale and technique effects, simple measures of openness per se, measured in a variety of ways, have very little impact on pollution concentrations.\(^{79}\) This is not surprising since the theory predicts openness per se is not relevant. In contrast, when they condition openness on country characteristics they find a highly significant, but relatively small, impact on pollution concentrations. In theory, this impact represents the composition effect created by further trade liberalization.

\(^{79}\) See Table 2, p.30 from our 1998, NBER Working paper No. 6707 which shows that none of our five different measures of openness had a significant effect on pollution concentrations.
To weigh the relative strength of pollution haven and factor endowment motives, they calculate country-specific elasticities of pollution concentrations with respect to an increase in openness. These elasticities should reflect a country's comparative advantage in dirty goods. A positive value for a country implies trade liberalization shifts its pollution demand to the right (reflecting a comparative advantage in dirty goods); a negative value implies trade liberalization shifts its pollution demand to the left (reflecting a comparative advantage in clean goods).

These elasticity estimates are plotted against per capita income in Figure 14 below.

If the pollution haven hypothesis were an accurate description of world trade in dirty goods, we would expect to see a strong negative relationship in Figure 14. Rich countries would have a comparative advantage in clean goods. The opposite should be true for poor countries. Nothing like this pattern emerges from the figure. In fact, the relationship is positive and significantly so. Moreover, since capital-to-labor ratios are higher in richer economies, the figure suggests that further trade liberalization will shift dirty and capital intensive production to the developed economies. That is, factor endowment determinants of trade appear to be dominating pollution haven motives, and richer countries appear to have a comparative advantage in emission-intensive goods.

To some extent this result should not be surprising. Although the methods here are different, the conclusions were foreshadowed in earlier work. For example, Table 2 was certainly suggestive of this result. Similarly, Walter (1973) calculates the direct and indirect environmental control costs in both U.S. exports and imports to find that U.S. exports are actually very dirty by this measure, more than 15% more than its imports. And Xu (1999) reports that in 1995, almost 80% of the world’s exports of environmentally sensitive goods come from the OECD countries. Finally, Figure 13 is consistent with the CGE evidence of Brown et al. (1991) predicting a reallocation of energy intensive manufactures towards the U.S. and Canada.

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[80] The magnitude of the elasticity is the percent change in SO2 concentrations associated with a 1% change in trade intensity (X+M)/GDP (via the composition effect).
[81] See Walter (1973), p67. 1.75% of the value of U.S. exports consisted of pollution-related costs, which is about 15% higher than the 1.51% estimated for U.S. imports.
Adding up scale, composition and technique effects

A second novel aspect of this paper is its method for separately estimating scale and technique effects. Previous work had been unable to separately identify these effects. The problem arises because both scale and technique effects are closely related to income levels. As a result, any increase in income is likely to shift both pollution supply and demand, making identification difficult. Antweiler et al. address this problem by exploiting the within-country variation in their dataset. Under the assumption that pollution policy is set at the national level, pollution supply is common for all cities within a given country. But cities differ in the scale of their output. Therefore, differences within countries across cities in their scale can be used to distinguish between scale and technique effects.\(^{82}\)

The estimates indicate that a 1% increase in the scale of economic activity raises pollution concentrations by approximately .25-.5%, but the accompanying increase in income drives concentrations down by approximately 1-1.5% via a technique effect. As a result, income gains created by freer trade lead to a net reduction in pollution concentrations from scale and technique effects.

The estimated gap between the scale and technique effect seems large, and should be investigated further.\(^{83}\) It is however consistent with the work of Pargal et al. (1996) who study the link between informal pollution regulation and community characteristics in Indonesia. Using plant level data, they find a 1% increase in community income drives pollution down by 2.8 - 4%; while a 1% increase in output raises pollution by between .6 -.7 %.\(^{84}\) The strong policy response is also consistent with the results of Hilton et al. (1998) on lead.

The full effect of trade liberalization on pollution z requires that estimates of scale, composition, and technique effects be added up. Differentiating their reduced form for pollution concentrations with respect to a change in trade frictions \(\beta\) yields:

\[^{82}\text{This is not the only means for separating these effects. The authors also exploit variation across time, and cross-country variation in the relationship between GDP and GNP.}\]
\[^{83}\text{Country specific estimates of course differ with some point estimates of the net effect being positive. The hypothesis that scale dominates technique is however rejected by every individual country in the sample.}\]
\[^{84}\text{See Pargal et al. (1996, Table 2, p. 1324.)}\]
\[
\frac{dz}{d\beta} \frac{\beta}{z} = \pi_1 \frac{dS}{d\beta} \frac{\beta}{S} - \pi_3 \frac{dI}{d\beta} \frac{\beta}{I} + \pi_4 \tag{4.10}
\]

where the \(\pi\) are estimated elasticities. The first term on the right hand side is the scale effect, the second the technique effect, and the last the trade-created composition effect. If the output and income change proportionately, (4.10) can be simplified to:

\[
\frac{dz}{d\beta} \frac{\beta}{z} = [\pi_1 - \pi_3] \frac{dI}{d\beta} \frac{\beta}{I} + \pi_4 \tag{4.11}
\]

Equation (4.11) is very useful, but since Antweiler et al. do not estimate how a fall in trade frictions affects income levels (i.e. \(dI/d\beta\)) further information is required.

One approach is simply to restrict conclusions to the sample-average country. Taking average value across countries yields \(\pi_1 = 0.26\) and \(\pi_3 = 1.57\) and \(\pi_4 = -0.38\). Noting that \(dI/d\beta > 0\), this implies that for the average country in their sample, free trade is good for the environment.

Another way to interpret the results is to recognize that the estimated composition effects of trade on the environment are relatively small for most countries. Moreover, CGE models predict even large trade liberalizations have only relatively small impacts on income and output. Once we factor these income gains through scale and technique effects, the net impact is likely to be smaller still. Putting this together, the evidence suggests that trade’s impact on the environment is likely to be small.

Many of those concerned about these issues have come to expect large consequences from trade liberalization because each of the leading hypotheses in the area predicts large changes in the composition of output from liberalization. But since these two motives for trade work against each other, the large effects predicted by either theory in isolation appear to be much smaller in practice.

Finally, although this work tends to confirm earlier work that suggested that the effect of trade on the environment is small, the explanation for this result is different. Earlier work tended to suggest that policy had no effect on trade patterns. In Antweiler et al., policy plays an important role in dampening the factor endowment effect.

**Sources of Growth and their Environmental Consequences**

80
One final interesting aspect of the Antweiler et al. analysis is its implications for the literature on the Environmental Kuznets Curve. To isolate the role of international trade in the data, they attempt to distinguish between the pollution consequences of income changes brought about by changes in openness from those created by capital accumulation or technological progress. This means their results can be used to investigate the hypothesis discussed in Section 3 that the pollution consequences of economic growth are dependent on the underlying source of growth.

As noted above, income gains created by freer international trade are, for an average country, beneficial to the environment. Neutral technological progress creates only scale and technique effects, and using the estimates mentioned earlier, one can conclude that it, too, is good for the environment in an average country.

However, growth via capital accumulation turns out to worsen the environment. To provide some idea of the magnitudes involved, Antweiler et al. conduct a back-of-the-envelope calculation assuming a constant capital share in GDP of 1/3. Using the same method as above, the full impact of capital accumulation is given by:

\[
\frac{dz}{dk} z = \pi_2 \frac{dS}{dk} k + \pi_2 - \pi_3 \frac{dl}{dk} I \tag{4.12}
\]

where \(\pi_2\) is the elasticity of pollution with respect to a change in a nation’s capital-to-labor ratio. This was estimated to be approximately \(\pi_2 = 1\). The scale and technique elasticities \(\pi_1\) and \(\pi_3\) are as given before. If capital’s share in income is 1/3, and population growth is zero over the time period considered, then (4.12) can be simplified. And employing the estimates given, we obtain:

\[
\frac{dz}{dk} z = \pi_2 + \frac{1}{3} [\pi_1 - \pi_3] = 1 + \frac{1}{3} [.26 - 1.57] = .56 > 0 \tag{4.13}
\]

Growth via capital accumulation alone raises pollution concentrations for our average country, even after taking into account the income effect on environmental policy.

This is an interesting result, despite its back-of-the-envelope flavor. It suggests that researchers investigating the environmental Kuznets curve need to pay more attention to the sources of economic growth. As well, it suggests that trade liberalization plus capital

\[85\] Population growth is assumed to be negligible.
accumulation is far less environmentally friendly than trade liberalization alone. We would stress, however, that once we depart from the standard analysis of trade liberalization to include its potential effects on capital accumulation, we should also include its potential role in facilitating technology transfer and accelerating technological change. Given the estimates presented earlier for neutral technological progress, these induced effects appear to work in the opposite direction from that of capital accumulation.

**Summary**

The studies reviewed in this section share the goal of explaining variation in pollution levels by reference to scale, composition and technique effects. While there has been some success in this regard, much more work needs to be done.

Along empirical lines several avenues are open. For example, since the authors have not estimated the impact of trade liberalization on income levels, factor accumulation, or technological progress, it should be clear that other methods to “add up” the estimated scale, composition and technique effects are possible. One such exercise was illustrated above, but clearly more analysis along these lines is warranted.

Similarly, the results are, at this point, specific to sulfur dioxide and it is difficult to know how or whether they may generalize to other important pollutants. It is known that sulfur dioxide emissions are highly correlated with other airborne pollutants, but again it would be worthwhile to examine the implications of trade for other major pollutants. Relatively large cross-country datasets exist for other pollutants, although the specific modeling strategy will need to be amended somewhat.

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86 This confirms a point made by Grossman and Krueger (1993).
87 Cole and Elliot (2001) use national emission data to investigate several pollutants. They are not able to distinguish between scale and technique effects, but use Antweiler et al.’s approach to attempt to isolate the composition effect of trade. They confirm the Antweiler et al results for SO2, and obtain similar results on composition effects for CO2. But they find that BOD and NOx appear to respond differently, suggesting that it is indeed important to expand the scope of work to include other pollutants. In a model with many pollutants and goods, there is no reason to expect that the relative importance of pollution haven versus factor endowment motives will be the same across all pollutants.
As well, Antweiler et al. estimated a relatively simple supply and demand model linking real income gains to changes in policy, but left under-explored the relationship between political economy elements and pollution outcomes. A sketch of a political economy theory is presented in Antweiler et al. but the extension of empirical methods to capture and account for these influences is left untouched.

Finally, their method of conditioning on country characteristics to weigh the relative strength of pollution haven versus factor endowment motives is admittedly coarse and inelegant. Further refinement along these lines should be possible.

5. Policy Implications

We now consider how theory and empirical work bears on two major policy questions. Much of the policy literature examines one of the following two questions: (1) Should trade policy be used to achieve environmental objectives? (2) Since environmental policy can substitute for tariff protection, should it be constrained by international trade law? Our answer to both questions is a tentative "no". Our answer is tentative because theory is ambiguous on these questions, and the empirical evidence required to resolve the ambiguity is currently lacking.88

5.1 Trade policy as a substitute for environmental policy

Since trade liberalization can be welfare reducing if environmental externalities are not fully internalized, does this mean countries should restrict trade to achieve environmental goals? The logic of using trade policy for environmental ends rests on two premises. The first is that freer trade for a country with lax environmental protection is likely to reduce welfare and harm its

88 Our review of the policy literature is highly selective. Some other surveys of the recent policy literature include Rauscher (2001) and Ulph (1997). Esty (1994) is a good non-technical introduction to the major policy issues and Bhagwati and Srinivasan (1996) is a good introduction to the distortions and targeting approach to these issues.
environment. The second is that a trade instrument such as a tariff is a good instrument to improve on this outcome.

There are good reasons to doubt both premises. First, there is very little evidence in favor of pollution haven driven trade. The earliest evidence on pollution havens fails to control for other determinants of comparative advantage; the evidence from the cross-sectional HOS studies is ambiguous and not quite to the point; and the evidence presented in Antweiler et al. (2001) favors a factor endowments view of world trade in dirty goods. Overall, the composition effects that are needed to drive the pollution haven effect are hard to find in the data. As well, there is evidence provided by many authors that income gains have a large positive effect on environmental quality. The current empirical evidence therefore supports a view where the technique effects arising from trade liberalization may be significant, while composition effects may in fact move dirty good production away from low-income developing countries to high-income developed countries.

The implication from theory is then clear: if low-income developing countries do not have a comparative advantage in dirty goods, then even without environmental protection, freer international trade will not be welfare reducing nor environmentally damaging. As we showed in section 4, trade liberalization in this case will bring both real income gains and improvements in environmental quality.

We should note, however, several caveats. The first is that the available evidence is both incomplete and subject to further scrutiny. The available studies deal with only a subset of possible pollutants, and there is very little empirical work examining how trade affects natural resource degradation. Natural resource degradation may be a key environmental impact of trade in resource-rich less developed countries. As well, we know of no empirical work specifically linking international trade to global pollutants. Since the studies define environmental outcomes quite narrowly, we should be wary of claiming too much. The evidence is also subject to further

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89 Even if researchers find a negative relationship between pollution regulations and competitiveness this does not imply that income-induced differences in pollution regulations are the only or even the most important determinant of trade. Regulations can of course matter to costs, while the pollution haven hypothesis remains a poor description of trade in dirty goods.
scrutiny. Given the existing problems in the literature and the embryonic nature of some of the research, future work with different pollutants, datasets, or countries may alter the results considerably.

There is of course evidence that in some situations trade liberalization has caused great environmental problems, be it in the Maquiladora region of Mexico or elsewhere. And environmental groups in the U.S. have presented a series of case studies or examples of environmental debacles linked to international trade. At present there is a tension between this evidence and the results of empirical work in the academic community. The difference may arise from sample selection if these agencies are not looking for the “good news” stories of trade’s effect, or they may reflect a real gap between the impact trade has on widely measurable environmental indicators used by academic researchers, and the more narrowly defined outcomes reported by these agencies. Nevertheless this disconnect is worrisome.

On theoretical grounds the question of whether we should use trade restrictions is more clear-cut. Trade restrictions are not a first-best instrument to deal with local environmental problems. Return to our small open economy model, replace trade frictions with a tax on trade, and assume environmental policy is not optimal. Assume Home exports dirty goods. For concreteness, assume Home levies a specific export tax of $t$ on exports. Then $p_1'$ in our previous analysis is simply $p - \tau$. \(^90\) Home’s representative consumer has utility:

$$U = V(p - t, I, z) \text{ where } I = G(p - t, K, L, z) + tE$$  \hspace{1cm} (5.1)

and $E$ is exports of $X$. Home’s pollution level is determined endogenously for any given pollution tax $\tau$ by\(^91\)

$$\tau = G_z(p - t, K, L, z).$$  \hspace{1cm} (5.2)

---

\(^90\) An export tax on $X$ is analytically equivalent to an import tariff on $Y$ – we could do the whole analysis in terms of a tariff on $Y$ and get exactly the same result.

\(^91\) The pollution tax revenue is included in the national income function $G$. If we had alternatively written $G$ as a function of the pollution tax $\tau$, (instead of as a function of $z$), then we would have to add the pollution tax revenue to the $G$ function to get total national income.
Now consider trade liberalization. The effect on welfare of a change in the export tax for given $\tau$ is:

$$
\frac{1}{V_I} \frac{dU}{dt} = \frac{dE}{dt} + (\tau - MD) \frac{dz}{dt}.
$$

(5.3)

An increase in trade barriers has two effects on welfare. It reduces exports, which is harmful as standard gains from trade are lost. And it reduces pollution because the export sector pollutes. Solving for the optimal tax on exports we find:

$$
t = -(\tau - MD) \frac{dz}{dt} / \frac{dE}{dt}.
$$

(5.4)

If pollution policy fully internalizes externalities ($\tau = MD$), the optimal tax on trade is zero. Rather than using trade barriers, countries can more effectively control environmental problems with instruments that are finely tuned to deal with the source of the problem, such as pollution taxes or quotas. This well-known result follows from the policy targeting literature (see Dixit, (1985)).

If environmental policy does not fully internalize externalities, then trade policy can be used as a second-best instrument to control pollution. Suppose, for example, the pollution tax is exogenously set to zero. Then if the only other available instrument is a tax on trade, its optimal level is:

$$
t = MD \frac{dz}{dt} / \frac{dE}{dt} > 0.
$$

(5.5)

By restricting trade, the pollution-intensive export sector is prevented from expanding to take advantage of trading opportunities, and this reduces pollution and raises welfare.

While the use of trade policy for environmental ends seems simple and attractive, there are several problems with the analysis above. The first is simply that once we adopt a multi-good framework, selective trade liberalization can usually improve welfare even with imperfect environmental policy in place [see Copeland (1994)].
Second, even if environmental policy is imperfect, trade may still be beneficial. As we demonstrated in section 4, the welfare results of trade liberalization depend on both a country’s comparative advantage and the instruments it uses for environmental protection. If a country has a comparative advantage in dirty goods, then the welfare impact of freer trade depends on whether imperfect regulation targets emission intensities or overall pollution. If it is the former, losses can occur; if it is the latter, gains are assured.

Alternatively, if a country has a comparative advantage in clean goods, then trade is necessarily welfare improving. This possibility has received far too little attention in the literature because many writers have taken it as obvious that countries with lax or low standards of protection must have a comparative advantage in dirty goods. This is however not always correct as shown earlier.

A third problem is that the conclusion that trade restrictions are a useful instrument follows from a theory that is silent on why environmental policy is not available. While there are surely countless stories as to why this may be true – asymmetric information, bureaucratic red tape, political economy factors, indivisibilities etc – the literature does not explain why tariff-setting is immune from these problems while environmental policy is hobbled by them. Instead we are asked to believe that whatever is responsible for constraining environmental policy has no effect whatsoever on our ability to target trade policy perfectly. This is a rather strong assumption. 92

92 The criticisms we have leveled against using trade policy for environmental outcomes need to be tempered when pollution is transboundary or global. If a country is large enough to influence the world price of the dirty good, then it can try to use trade policy to lower the price of the dirty good so that foreign countries generate less transboundary pollution (See Markusen, 1975).

Such a policy, however, suffers from a number of problems. It is unlikely to be effective unless all countries coordinate their trade policy. Consider a three-country model. Suppose both East and West produce X; and West’s production of X is dirty while East’s is clean. If Home unilaterally tries to reduce West’s pollution with a tariff, then West can instead export to East, and East can export to Home. Home’s tariff on West’s dirty production may have almost no effect on pollution in a multi-country world.

As well, a trade restriction can have perverse effects if there are alternative uses for a fixed factor used by the environmentally intensive industry. Suppose North uses a tariff to restrict lumber imports from South in an effort to protect forest habitat in the South (which Northern residents value). Then with the economic viability of the lumber industry diminished, Southern producers may find it profitable to burn the forest and convert the land to agricultural use.
5.2 Environmental policy as a substitute for trade policy

One of the most contentious issues in the debate over trade and the environment is the possibility that environmental policy may be used as a substitute for trade policy. A major concern is that once trade agreements reduce trade barriers, governments will weaken environmental policy to help shield give domestic firms compete with their foreign rivals. That is freer trade may harm the environment because of an endogenous weakening of environmental policy. We refer to this motive as tariff substitution, as environmental policy is substituting for the lack of available trade policy instruments, typically because tariffs and quotas are constrained by trade agreements.

To investigate this issue we must first identify why governments have an incentive to protect local firms, (so there is a need for a trade agreement). The literature has focussed on three motives for protection: (1) the *terms of trade motive* arises in standard competitive trade models when a country is large enough so that its trade policy can affect world prices; (2) a *strategic motive* for protection arises in models where there is market power at the firm level – in these models, governments can intervene to try to give their firms a strategic advantage over foreign firms; and (3) a *political economy motive* for protection arises even in small competitive economies when governments respond to interest group pressure.

Although the details of government behavior vary across the motives for protection, the same key insight emerges from each: signing a free trade agreement limits the instruments of protection available, but does not eliminate the pressure on the government to protect. If the government has access to instruments that can substitute for trade policy, then they can be used to undermine a trade agreement. This has important implications for the linkage of trade and environmental policy.

These problems arise because a trade restriction is not the first best way to deal with environmental problems in foreign countries. The first best policy calls for a negotiated agreement in which the foreign country uses environmental policy instruments to target pollution in return for a possible transfer from Home. Trade policy may still be useful as part of an enforcement mechanism because it can help to implement a more severe penalty for deviations from agreements.
Once we have established that governments may have a motive to use environmental policy as a substitute for trade policy, the next issue is how the environmental policy can be used for trade objectives. There are two principal mechanisms - environmental policy can be used as a trade instrument either by affecting local cost conditions or as a means of restricting access to the local market. In some cases, it can do both at once.

When pollution is generated during production, environmental policy tends to be directed at local firms, and so most of the scope for manipulating policy for protective purposes lies in either loosening or tightening policy to raise or lower local firms’ production costs. However, countries have sometimes attempted to make access to local markets contingent on the process by which goods were produced in the source country. That is, countries may wish to block access to local markets unless foreign producers meet certain environmental standards. This method of protection is for the most part not legal under WTO rules, and has been a considerable source of controversy.\(^{93}\)

On the other hand, when pollution is generated during consumption (such as with automobile emissions), environmental policy targets the characteristics of products, and so applies to both local and imported products. Consequently policy aimed at consumption-generated pollution can be used to restrict market access for non-conforming foreign products, as well as to affect production costs of both local and foreign firms.

Although the details will differ across model types, the terms-of-trade, strategic trade, and political economy models all predict that governments have an incentive to take advantage of product standards to protect local firms. To avoid the use of product standards as a protectionist device, trade agreements typically require a national treatment rule. Under a pure national treatment regime, countries are allowed to impose any environmental standards they choose, but the standards applied to foreign products should be no less stringent than that applied to local products. That is, a national treatment regime attempts to circumvent protectionist tendencies by

\(^{93}\) The US ban on imports of tuna from Mexico because Mexican fishing practices led to porpoise deaths is perhaps the most prominent example. For a discussion of this and other cases, see Esty (1994).
enforcing a non-discrimination rule. Unfortunately, a national standard does not eliminate the potential for governments to manipulate environmental policy for protective purposes.\textsuperscript{94}

Because of the potential for governments to manipulate standards within a national treatment regime, recent trade agreements have placed more restrictions on the ability of governments to choose their environmental standards. Rather than choosing any standard, governments have to demonstrate there is scientific evidence to support their case, and that restricting access to products that do not meet a standard is the least trade distorting means of achieving their policy objective. This issue continues to be one of the critical sources of conflict between trade liberalization advocates and environmentalists.

While it seems clear that trade agreements must put some limit on the ability of countries to employ national standards as a protective device since product standards have a direct and potentially large impact on trade flows\textsuperscript{95}, it is far less clear that trade agreements should restrict environmental policy more generally. The argument against altering current trade agreements to correct for the use of environmental policy rests on two pillars. The first is that the theoretical results finding a possible abuse of environmental regulation for trade ends is fragile. Altering relatively innocuous assumptions can overturn the results. The second argument is that even if theory has found the possibility for environmental policy to play other roles, the empirical evidence supporting this role is very thin. Since both the theory and empirical justifications for action are presently weak, while the costs and potential for abuse real, we argue for no explicit linkage.\textsuperscript{96} To develop these arguments further, we consider the theoretical and empirical evidence further below.

\textbf{5.2.1 Tariff Substitution}

\textsuperscript{94} This should come as no surprise and follows quite straightforwardly from the logic behind “Raising Rivals Costs” in Salop and Sheffman (1983).
\textsuperscript{95} See Bagwell and Staiger (2001) for a disarmingly simple remedy for the standards problem.
\textsuperscript{96} For explicit studies of the linkage question, see Edderington (forthcoming) and Limao (2001).
Consider a competitive world economy with two countries and suppose governments have only two policy instruments available: trade taxes and pollution taxes. Both instruments affect a country's import demand and export supply and, we assume, can affect its terms of trade. As well, both policies affect environmental quality.

First suppose governments choose both trade and environmental taxes non-cooperatively. Each government uses its two instruments to maximize the utility of its representative consumer. Let t be Home's ad valorem import tariff and let $\tau$ be its pollution tax; and let M denote imports and E denote exports. The corresponding Foreign variables are denoted with an asterisk (*). Any tax revenue is rebated in lump sum to the consumer.

Consider Home's problem. Suppose Home imports the pollution intensive good and exports the clean good. With these policy instruments in place, the consumer's budget constraint is:

$$I = G(p(1 + t), K, L, z) + t Mp$$

(5.6)

The government chooses tariffs and pollution policy to maximize consumer's utility subject to the budget constraint (5.6) for given levels of Foreign's policy instruments. The first order conditions for the choice of t and $\tau$ are:

$$-M \frac{dp}{dt} + tp \frac{dM}{dt} + (\tau - MD) \frac{dZ}{dt} = 0$$

(5.7)

$$-M \frac{dp}{d\tau} + tp \frac{dM}{d\tau} + (\tau - MD) \frac{dZ}{d\tau} = 0$$

(5.8)

where recall that MD denotes marginal damage. Noting home imports must equal foreign exports ($E^*$), we have

$$\frac{dM}{dt} = E_p^* \frac{dp}{dt}$$

and by substituting this into (5.7) and (5.8), we can find the optimal policy pair:

$$\tau = MD$$

(5.9)

$$t = \frac{1}{\varepsilon^*}$$

(5.10)
where \( \varepsilon^* \equiv \frac{pE^*}{E^*} > 0 \) is the elasticity of the foreign export supply function.

The solution reflects the policy targeting literature again: externalities are fully internalized with environmental policy, and tariffs target the terms of trade [see for example, Dixit (1985)]. When governments are unconstrained in their choice of policies, there is no incentive to weaken environmental policy to give local firms a competitive edge over foreign firms – this can be more effectively accomplished by using tariffs alone.

Similar results apply to an exporter of pollution intensive goods (the Foreign country in our example). The foreign government's optimal policy is to fully internalize externalities and either protect its import-competing industry \((Y)\) or equivalently to tax exports of the polluting good.

When both countries use trade policy to improve their terms of trade, the world ends up in a standard non-cooperative tariff game. This pushes them inside the global Pareto frontier because trade barriers drive a wedge between prices in the two countries. Both countries can therefore gain from a trade agreement that moves them back to the frontier. This is the motive for entering into a free trade agreement in our model.

Suppose the two countries reach a binding agreement to eliminate tariffs. What happens to environmental policy? Setting the tariff equal to zero in (5.8) yields:

\[
\tau = MD + M \frac{dp}{dz} / \frac{d\tau}{dz} < MD .
\]  

(5.11)

In response to the free trade agreement, Home’s optimal pollution tax diverges from marginal damage. Home still has an incentive to protect its import-competing firms, but with trade barriers eliminated, it has to fall back on second best instruments. If environmental policy is the only other instrument available, Home provides an implicit subsidy to its import-competing industry by setting the pollution tax below marginal damage.

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\textsuperscript{97} As is well known, a large country can “win” a trade war in the sense that it is better off in the tariff-ridden equilibrium than in free trade. But because such an equilibrium lies inside the Pareto frontier, even a “winner” of the trade war has an incentive to negotiate for a point on the Pareto frontier. As Mayer (1981) notes, any point on the Pareto frontier can be implemented with free trade combined with a lump sum transfer. A large country would demand a lump sum transfer (or some other concession) in return for free trade.

92
The discussion above has focused on the incentives facing the importer of polluting goods. The exporter of polluting goods also has an incentive to look for an alternative to trade policy. In this case, as mentioned previously, Foreign has an incentive to reduce the world supply of the polluting good, and hence elimination of tariffs will cause it to tighten up environmental policy:

\[ \tau^* = MD^* - E^* \frac{dp}{d\tau^*} > MD^*. \] (5.12)

In this model, importers of pollution intensive goods have an incentive to loosen up environmental policy to subsidize local production, while exporters have an incentive to tighten up policy to tax production.\(^98\)

The result here is a special case of a more general result, which is that when there are multiple policy instruments available to governments, a free trade agreement that restricts only a subset of instruments is an incomplete contract that can be undermined as governments substitute towards unconstrained instruments.\(^99\) In this context, the option of manipulating environmental policy to improve the terms of trade creates a loophole in the trade agreement.

The result that governments can use environmental policy as a substitute for trade policy also appears in both the strategic trade and political economy literatures. In strategic trade papers, there is typically a two stage game: government policy is set in the first stage, and imperfectly competitive firms move in the second stage. As Brander and Spencer (1984, 1985) showed, if governments can make binding policy commitments in the first stage, they can give their firms a strategic advantage in the latter stage. In these models, once trade taxes and subsidies are eliminated, governments have an incentive to switch to other instruments, including environmental policy if available (see Barrett, 1994; Conrad 1993, Kennedy, 1994).

To identify this motive, consider a partial equilibrium model with three countries, East, West and South. East and West each have one firm producing a dirty good that is sold only to the

\(^{98}\) On this point see Baumol and Oates (1988), Markusen (1975) and others.\(^{99}\) See Copeland (1990) for an early model of this process and Bagwell and Staiger (2001) for a recent examination and a suggested solution. The key to Bagwell and Staiger’s results is that they assume WTO obligations over market access really bite and hence the contract is “complete” once we recognize the bargain was not over the particulars of tariffs but rather market access.
South – that is, all production is exported.\textsuperscript{100} And, for clarity, assume only one country, say West, is policy-active. The game proceeds in two stages. In the first stage, West chooses its pollution tax $\tau$, and in the second stage, the two firms choose output simultaneously.

Because the model is partial equilibrium, and there is no domestic consumption of the dirty good, we can write West’s welfare function as:

$$W = \pi(x, x^*, z) - D(z)$$

where $\pi$ is profits of West’s firm, $x$ and $x^*$ are West and East output of the dirty good, $z$ is West’s pollution ($\pi_z > 0$), and $D$ is the pollution damage function.

If there were no Eastern firm, the West’s government would simply choose the pollution tax so that the marginal benefit of polluting equals marginal damage:

$$\pi_z = MD$$

(5.13)

where $MD \equiv dD/dz$. Moreover, in response to the pollution tax, the firm would choose its emissions level such that

$$\tau = \pi_z$$

(5.14)

And hence the solution would be implemented with a pollution tax set equal to marginal damage ($\tau = MD$).\textsuperscript{101}

However, when the Western firm competes with its Eastern rival, the Western government has an incentive to use environmental policy to help its firm gain a strategic advantage over its rival. In this case, West’s optimal pollution policy is determined by:\textsuperscript{102}

$$\pi_z + \pi_{x^*} \frac{dx^*}{d\tau} \frac{dz}{d\tau} = MD$$

(5.15)

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\textsuperscript{100} Home and foreign goods may be either homogeneous or imperfect substitutes – we need home’s demand to fall when foreign output rises.

\textsuperscript{101} Note however the role played by no domestic consumption in West.

\textsuperscript{102} Because the Western government moves first, it uses the first order conditions from the second stage Cournot game to predict how its policy affects the final outcome. Because the Western firm maximizes profits treating eastern output as given, we have $\partial \pi / \partial x = 0$, which we have used to get (5.15).
Reducing the pollution tax (and therefore raising emissions) yields two benefits now – there is the direct reduction in the domestic firm’s costs (hence the increase in profits given by \( \pi_z \)); but as well, there is a strategic effect – a reduction in Home’s pollution tax lowers the home firm’s costs. This shift out the home firm’s reaction function in the output game, and causes the foreign firm to reduce its output (as long as reaction functions slope downward). That is, a weakening of Home’s environmental policy allows the Home firm to credibly commit to produce more output, which leads to higher profits for Home. The home firm always has an incentive to commit to more output, but such a commitment is not credible. A weakening of Home’s environmental policy helps the local firm out by making such a commitment credible.

The optimal pollution policy for the Home country can now be written as:

\[
\tau = MD - \pi_z \frac{dx^*/d\tau}{dz/d\tau} < MD
\]

where Home provides an implicit subsidy to the domestic firm by setting the pollution tax below Marginal Damage. Again we find environmental policy distorted.

And finally in the political economy literature, governments respond to political pressure and use policies to redistribute income from one interest group to another. If trade policy and environmental policy are the available instruments, then once tariffs are eliminated, governments will manipulate environmental policy to help favored groups. Pollution taxes will be above or below marginal damage depending on the political strength of competing interest groups. To illustrate the implications of this approach for environmental policy, consider a simple political support model. Suppose there are two agents: Labor and Capital, and suppose their utility functions take the form:

\[
U = \frac{I}{\beta(p)} - D(z)
\]

Typically, this literature makes assumptions on demand and cost conditions to ensure that reaction functions slope down and a stability condition is satisfied.

This linear form ensures the marginal utility of income is unaffected by redistributions across the two groups in society altering the income distribution. This is a common assumption in the political economy literature. This simplifies the calculations tremendously but is not necessary for our main point here.
where $I$ is income, $\beta$ is a price index, and $D$ the pollution damage function which is increasing and convex. The production side of the model is the basic competitive model we used earlier in the essay. Assume a small open economy (with goods prices fixed) to eliminate the terms of trade motive for intervention.

Suppose that the government places a higher weight on capitalists than workers, and suppose that the only instrument available is the pollution tax. The government chooses pollution to maximize:

$$W = U^L + (1 + \lambda)U^K$$

where $U^L$ is the utility of Labor, and $U^K$ is the utility of Capital. Then solving as before for the optimal pollution tax now yields:

$$\tau = 2\beta \frac{dD}{dz} - \lambda \beta \frac{\partial U^K}{\partial z} = MD - \lambda \beta \frac{\partial U^K}{\partial z} \quad (5.17)$$

An increase in allowable pollution raises the return to capital and lowers the return to labor in the model of section 3. Consequently, capitalists prefer more pollution than at the socially efficient point (where $\tau = MD$); that is, in the relevant range, we have $\partial U^K/\partial z > 0$. If the government gives preferential treatment to capitalists so that $\lambda > 0$, then it will subsidize the pollution intensive industry by setting a pollution tax below the social marginal damage. If the government gives preferential treatment to labor, then $\lambda < 0$ and the pollution tax is below social marginal damage.

**Discussion**

We have now shown how environmental policy may be distorted to meet the goals of trade policy. While the terms-of-trade, strategic trade, and political economy models all can generate the prediction that freer trade will increase the incentive for governments to manipulate environmental policy, they are of course subject to several criticisms as well. Criticisms fall into three categories: (1) exogenous restrictions on instrument choice; (2) fragility of results; and (3) lack of empirical evidence. We discuss these in turn.

All of the models suffer from a common weakness, which is that environmental policy is typically not the best instrument to achieve the government’s non-environmental targets. In the political economy models, the government wants to increase the income of some interest groups
at the expense of other groups. Environmental policy can accomplish this indirectly by affecting cost conditions and thereby affecting factor returns via market effects. However, a more direct way of raising income is simply to use direct transfers. If these are rules out, taxation rules can be manipulated. Or direct production subsidies can be used. That is, there are many other instruments typically available to governments that will do a better job of transferring income, and likely at lower social cost per dollar transferred.

Similarly, in the terms of trade or strategic trade models, if a tariff is eliminated, governments could take advantage of the well-known result that a tariff is equivalent to a consumption tax combined with a production subsidy. That is, if the government signs a treaty to eliminate tariffs, it can exactly replicate the effect of the tariff by using domestic tax and subsidy policies – there is no need to manipulate environmental policy.\(^\text{105}\)

Moreover, environmental policy is less effective and more costly than these other instruments. For the most part, the literature has dealt with this problem by restricting the policy space. Most models simply assume that environmental policy and tariffs are the only available instruments. But once we open up the possibility that governments have other instruments available, the likelihood that these models will predict trade agreements will lead to strategic manipulation of environmental policy is substantially diminished.

This weakness in these models has been recognized for quite some time – Rodrik (1995) identified it as one of the key challenges for the political economy literature, and Wilson (1996) pointed out its implications for the environmental “race to the bottom” literature. However, it remains a fruitful area for further research.

A second critique of this literature takes the restrictions on the policy space as given, but argues that the results are either extremely fragile, or rely on an incredible degree of coordination across levels of government. For example, it is well known that results in the strategic trade policy literature are sensitive to assumptions about both market conduct and market structure. The same is true here. If we alter the partial equilibrium model above by assuming the domestic

\(^{105}\) If production subsidies are disallowed by trade rules, then we can resort to R&D subsidies that lower marginal costs. If R&D subsidies are not available, there are many other potential ways of subsidizing firms that may be more palatable than weakening environmental policy.
and foreign firm sell differentiated products and choose prices rather than quantities, then the relationship between the optimal pollution tax and marginal damage is reversed. In this case, we write domestic welfare in terms of prices:

\[ W = \pi(p, p^*, z) - D(z) \]  

(5.18)

and solving for the optimal pollution tax, we find:

\[ \tau = MD - \pi_{p^*} \frac{dp^*/dz}{d\tau} > MD \]  

(5.19)

the pollution tax is above marginal damage. The reason for this is well known: with price competition, domestic and foreign prices are strategic complements. Consequently, the home firm has an incentive to commit to a higher price, because the foreign firm would respond by raising its price as well and both firms would benefit from the higher prices. The home government can help its firm make this commitment credible by taxing it; that is by tightening environmental policy. In doing so, Home’s reaction function shifts out and home gets a strategic benefit from the increase in foreign price.

The key point here is that once we alter our assumptions on market conduct to allow for price competition, the Home government’s incentive to give its firm a strategic advantage leads to an argument for an export tax and not an export subsidy. If we remove the ability of government’s to use export taxes, then exporting countries have an incentive to tighten, not loosen environmental policy.

Even if we retain our homogenous product, Cournot model, the policy implications are also sensitive to assumptions about entry and market structure. As Barrett (1994) noted [following earlier work by Dixit (1984)], when there are two or more domestic firms, part of the potential rents from exporting are dissipated as the two domestic firms compete with each other. The optimal policy to counter this competition is an export tax (or quota), which is our case is a tightening of environmental policy. That is, on the one hand, the government has an incentive to subsidize the domestic firms to give them a strategic advantage in their competition with the foreign firm, but on the other hand, there is an incentive to tax the domestic firms to encourage
cartelization by domestic firms. In simple linear models, the taxation motive tends to dominate once there are more than a small number of domestic firms. That is, once we move away from a single domestic exporting firm to a model with several imperfectly competitive domestic firms, we revert to the standard result that emerges from competitive models, which is that the government has an incentive to raise the pollution tax above marginal damage to tax domestic firms to improve the terms of trade.

Criticism also comes from environmental economists who note while trade policy is almost exclusively determined by central governments, much of environmental policy is set at the local, regional, or state level. Therefore, in order to put into place the terms of trade motivation for altering environmental policy we need a great deal of coordination between different levels of government. Moreover, since states, regions and even cities differ in the composition of their factors and goods production it is not clear this cooperation would follow since their constituents may well be hurt by a price change that at the national level, would be welfare improving.

Political economy models fare better in this regard since local authorities have it in their power to relax environmental standards to help local firms. However, these models are not immune from all of the problems mentioned above. For example, several authors have considered political economy models with both trade policy and environmental policy, using a Grossman-Helpman (1994) framework. Schleich (1999) pointed out that the usual targeting results hold in this model, so that if tariffs are available, there is no incentive to distort environmental policy (because in these models, the government wants to minimize the social cost of raising the income of favored groups). And as we demonstrated above, the political economy approach does not always imply that environmental policy will be too weak. If a polluting sector has relatively weak political influence, then environmental policy may be tightened up in that sector to free up resources for other more favored sectors. As Conconi (2001) points out, if environmental groups are sufficiently strong relative to industry groups, then pollution policy may be more stringent than the Samuelson rule would require.

Overall, the theoretical literature on tariff substitution does predict that governments may have incentives to manipulate environmental policy to help domestic firms in response to trade liberalization. There is no uniform prediction as to whether policy will be too tight or too weak,
and the predictions on the conditions under which governments will resort to tariff substitution are sensitive to the assumptions of the set of available alternative instruments and market conduct. This is an area where empirical evidence is badly needed.

The empirical evidence on tariff substitution is, however, very limited. As we discussed earlier, the existing studies linking pollution abatement costs to import penetration are inconclusive, and while the evidence of Antweiler et al. (2001) is suggestive of weak comparative advantage effects arising from regulations it does not offer conclusive evidence on this score. Edderington and Minier (2001) and Levinson (1999) both find evidence that by treating pollution regulations as endogenous, pollution abatement costs are significant determinants of import penetration. But Levinson points out that this endogeneity can arise for many reasons and not just tariff substitution. Consequently, their evidence on the endogeneity of environmental control costs is not necessarily evidence that environmental policy is set with regard to its international trade consequences. In short, we have little empirical evidence suggesting that even if governments wanted to substitute environmental for trade policy, then this would have large effects on trade flows, prices, or welfare.

A couple of studies have attempted to directly test for policy substitution. Eliste and Fredriksson (forthcoming) argues that governments will weaken environmental policy to shelter industries newly exposed to freer trade and provides some evidence from the farm sector to support this. Gawande (1999) finds evidence that governments do substitute non-tariff barriers for other instruments of protection, suggesting that the concern about loopholes in trade agreements is well founded; however, he does not isolate the effect on environmental policy. This is another area where much more empirical work is required to help clarify the policy debates.

6. Conclusions

The debate over the environmental consequences of freer trade has proceeded with little reference to firm evidence. While this state of affairs is perhaps not surprising given the data
constraints and the newness of the research agenda, there is no need for this state of affairs to continue. Despite assertions to the contrary, the environmental implications of free trade are not self-evident and it is only through careful empirical work that we are likely to determine the direction and magnitude of trade’s effect. Since the impact of trade on environmental outcomes is complex, the need for empirical work guided by theory is very high.

In reviewing the trade, growth, and environment literature, we find that much of the promise provided by Grossman and Krueger’s NAFTA study has been left unfulfilled. The subsequent literature has for the most part ignored the key components of the Grossman and Krueger analysis: the link between theory and empirical analysis, and the methodology of adding up of scale, composition and technique effects. Instead of improving on Grossman and Krueger’s methods, the subsequent literature has focused almost exclusively on the role of income effects in determining environmental outcomes. By doing so, this literature has limited the roles that natural resources or capital abundance may play.

And instead of fleshing out a theory of how trade, growth and the environment interact to guide empirical estimation, the subsequent literature has, for the most part, ignored the role of theory despite the important conceptual role that theory played in the original GK study.

This essay has put forward perhaps the simplest general equilibrium framework in which we can examine trade, growth and environmental outcomes more systematically. If we adopt the simple general equilibrium pollution supply and demand view we have put forward in this essay, then several conclusions follow.

The first is simply that while incomes per capita are likely to be an important determinant of pollution policy (or pollution supply), actual pollution outcomes reflect the impact of other national characteristics as well (since they determine pollution demand). The existing literature’s focus on income effects is misplaced. This focus has manifested itself most starkly in the empirical studies of the EKC but it is also present in the empirical trade literature searching for pollution havens. It has led the former to doggedly link environmental outcomes to income per capita alone, and led the latter to find pollution havens when Southern economic development is a far more likely candidate.
Our theoretical framework suggests that linking environmental outcomes to income per capita alone is unlikely to be successful – just as predicting the pattern of trade in dirty goods across countries by relative income levels alone is unlikely to be successful. Income levels are important but they aren’t everything. And recent research finding a sensitivity of EKC relationships to time periods or data may reflect the workings of important excluded national characteristics. If so, this would echo our concerns with the empirical literature linking trends in dirty good production and trade to income levels.

Once we admit that national characteristics other than income are relevant in predicting dirty industry trade, we must also admit these same characteristics should be linked to pollution levels in any EKC study. A factor endowments view of world trade in dirty goods carries with it, as a logical consequence, a view that the shape of the EKC reflects other national characteristics such as factor composition. Future research should move away from estimating highly restricted models of pollution determination to consider alternatives giving a significant role to both natural resources and capital abundance.

A second conclusion flowing from our analysis is that once we interpret pollution levels and the stringency of regulation as equilibrium outcomes, then pollution abatement costs are no longer independent of industry attributes. Consequently, measures of trade performance (such as import penetration) and pollution abatement costs are both endogenous variables. Therefore, the common finding of a weak or non-existent relationship between pollution abatement costs and import penetration is likely to be a symptom of econometric problems and not evidence that environmental regulations are irrelevant. And the occasional finding of a positive relationship between pollution abatement costs and measures of competitiveness is surely not prima facie evidence of the “Porter Hypothesis”.

It is interesting to note that the original Grossman and Krueger study contained a (short, footnoted) discussion of problems arising from the potential endogeneity of trade policy. In reviewing a counterintuitive signs on tariffs in their own cross-sectional industry analysis (tariffs were positively related to imports), Grossman and Krueger offered the possibility that tariffs may be endogenously determined with imports via a political economy process. Our review of the evidence suggests we extend this original critique to include the variable reflecting pollution
abatement costs – since this variable reflects the stringency of environmental regulation.

Examining this endogeneity problem further should be a major focus of future work in this area.

A final implication of our view is that while the income gains created by trade will shift all countries pollution supply upwards, the shift in pollution demand created by a trade liberalization depends on a country’s comparative advantage. It is only after determining a

can we identify the composition effect of trade; moreover the sign of this composition effect depends on the relative strength of pollution haven versus factor endowment motives for trade. This finding, although simple, reinforces the role that theory must play in any future investigation. Given current data constraints and the politically charged atmosphere surrounding the trade and environment debate, researchers should rely more and not less on theoretical models. And while the simple supply and demand model of Antweiler et al. (2001) is carrying a heavy burden in isolating and measuring the effects of trade, it could play an important role in bringing more theory to bear on this question. Future work in this area should be attempting to refine, extend, and improve on these methods.

Research examining the question of trade’s impact on the environment is in its third decade. Despite this long tradition, very little is known with certainty. And without further guidance from theory, empirical work will flounder, and remain at best, suggestive. But if this is true, then many of the most important policy debates in this literature will remain unresolved. While it appears on both theoretical and empirical grounds that the use of trade policy for environmental ends is often bad public policy, it is unclear whether trade agreements need to account for the possible substitution of environmental measures for lost trade protection. Theory alone cannot answer this question, since predictions from the policy literature are often quite fragile and depend on knowledge of government motivation, instrument choice, and the strategic interaction across firms. Although it is somewhat disappointing that we do not yet have clear answers to all of the relevant questions, we have made a good start in defining the relevant research questions, introducing theory useful to the discussion, and to a smaller extent, combining theory and empirical work to obtain estimates of key magnitudes.
7. References


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