The Environment and Trade

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Abstract

Reflecting the emphasis of recent work in the field of trade and the environment, this review focuses on empirical issues, primarily econometric estimates of the pollution haven effect and simulation-based calculations of carbon leakage. A brief discussion of the theory explains why intuition from partial equilibrium models may not carry over to a general equilibrium setting.

1. INTRODUCTION

International trade complicates many issues that interest environmental economists, and the presence of environmental problems qualifies some important conclusions from trade theory. Neoclassical economic theory emphasizes the efficiency of markets, treating market failures as epiphenomena. Environmental economics, in contrast, focuses on market failures that create and make it difficult to solve environmental problems. International trade extends the reach of markets, thereby extending the range of possible market failures and changing the set of policies to combat those failures. The study of environmental regulation seeks to remedy environmental problems without creating significant additional distortions, ones that might make the cure worse than the disease.

Three fundamental ideas, familiar to virtually all economists, underpin the study of trade and the environment: the theory of comparative advantage, the theory of the second best, and the principle of targeting. The theory of comparative advantage provides the basis for thinking that international trade has at least the potential to increase welfare among all trading partners. This theory supports the presumption that trade increases welfare and that nations should adopt liberal trade policies: The burden of proof is on those who want to restrict trade.

The theory of the second best states that in a world with two or more distortions, e.g., market failures, the reduction of one distortion may either increase or lower welfare. The direction of welfare change depends on the relative magnitude of the various distortions and on the manner in which the distortion being reduced interacts with other distortions. For example, if a country restricts trade, and in addition production of one good creates a negative environmental externality, there is both a trade and an environmental distortion. In this example, trade liberalization exacerbates the environmental distortion if and only if trade increases production of the environmentally intensive (hereafter, "dirty") good. If the trade distortion is initially small, i.e., if domestic prices are initially close to world prices, then trade liberalization has only a second-order, direct, positive welfare effect, measured by a triangle. If the environmental distortion is large, the indirect effect of trade liberalization, via the environment, creates a first-order welfare change, measured by a rectangle. Because triangles are small relative to rectangles, as Harberger observed, the direction of the net welfare change depends in this case on whether trade ameliorates or exacerbates the environmental problem.

After 50 years of post–World War II trade liberalization, followed by 15 years of drift, the trade regime is arguably relatively liberal. If one accepts this assessment, then further trade liberalization may produce only second-order direct welfare benefits. If one also accepts that we are faced with severe environmental problems, then changes that affect those problems likely produce first-order welfare effects. Thus, the view that we inhabit a world with a liberal trade regime and serious environmental problems makes it reasonable to view some trade-related issues through the lens of an environmentalist. That conclusion does not create a presumption either for or against trade liberalization because environmental problems can either reinforce or overturn the welfare argument in favor of liberal trade. In the example above, the net welfare effect of trade liberalization depends on whether the liberalizing country imports or exports the dirty good. In general, an environmental distortion creates a rationale for either a trade restriction or a trade subsidy. Without knowing the particulars of the problem, we cannot say which.

The third fundamental idea, the principle of targeting, reminds us that, even when environmental distortions do create a rationale for a trade restriction, that policy is unlikely to be optimal. Except in the rare circumstances in which trade is actually the cause of the environmental problem, trade policy can ameliorate the problem only by creating a secondary distortion. The first-best policy targets the environmental problem directly, e.g., by means of an emissions tax, thereby avoiding the secondary distortion.

The considerations discussed above mean that we cannot dismiss the possibility that liberalized trade contributes to environmental problems and that in some cases it would be worth sacrificing some of the benefits of trade to improve the environment. However, there is no presumption that trade harms rather than improves the environment. Even when we can make a case for the former, trade policy is seldom the best remedy.

In a closed economy, a government is able in principle to control levels of pollution by means of domestic policies. Trade undermines the efficacy of domestic policies, and international trade agreements limit the use of trade restrictions. These two facts animate the field of trade and the environment. A stricter domestic environmental policy increases production costs in dirty sectors. Certainly in a partial equilibrium setting, and often in a general equilibrium setting, these policies reduce a country's domestic supply of the dirty good (relative to the supply of clean goods), shifting up and out the country's excess demand for the dirty good. The stricter domestic environmental policy encourages the rest of the world (ROW) to increase production of the dirty good, increasing pollution in ROW.

Concerns about shifting dirty-good production abroad have both economic and environmental foundations. Stricter environmental policy reduces the return to factors trapped in the dirty sector. In a closed economy, both producers and consumers bear some of the incidence of an environmental policy such as a pollution tax or an emissions quota. Although trade reduces the aggregate economic cost of such a policy, trade shifts the incidence almost entirely onto producers, when pollution arises from production rather than from consumption (McAusland 2008). For many reasons, including problems of collective action, producers are likely to be more effective than consumers at lobbying against policies that harm them. Therefore, trade liberalization is likely to increase effective domestic opposition to environmental policies.

In the case of global pollutants such as greenhouse gases or transnational pollutants such as SO_2 (a cause of acid rain), the domestic environmental benefit of decreased domestic emissions is partly or entirely offset by increased ROW emissions. The increased ROW emissions due to decreased domestic emissions (leakage) are a particular concern with climate policy. Even in the case of pollutants that affect only local air and water quality, there may be objections to shifting pollution abroad. As with most questions at this level of generality, there are efficiency arguments on both sides of the issue. If the country that imposes the stricter environmental policy has already been doing a better job of correcting the pollution externality, compared with those countries that respond by increasing pollution, then the theory of the second best suggests that the net aggregate welfare effect of the stricter domestic policies is negative: A small domestic distortion (a triangle) has been made still smaller at the cost of increasing a large ROW distortion (a rectangle). However, if environmental policy is set optimally in both regions, then the shift in pollution increases efficiency rather than exacerbating a distortion: It is a response to real as opposed to apparent comparative advantage (Chichilnisky 1994), and it improves welfare even in the region that increases pollution.

The idea that dirty industries migrate to regions with lax environmental policies is known as the pollution haven hypothesis (PHH). Some writers like to distinguish the PHH from the pollution haven effect to emphasize that many considerations determine the location of industries. All else being equal, stricter environmental policy is likely to reduce a country's comparative advantage in dirty goods, but other things are seldom equal and in fact tend to be correlated with environmental policy. For example, dirty goods tend to be capital intensive, and rich countries tend both to be relatively well endowed in capital and to use stricter environmental policies. There is no reason to think that stricter environmental policies overwhelm a larger relative endowment of capital.

Copeland & Taylor (2003, 2004) summarize advances (many of which they produced) in the field of trade and the environment. The debt that this review owes to their work will be evident to anyone familiar with their writing. In an effort to avoid duplication, I provide only a short discussion of theory and emphasize the empirical work subsequent to their reviews.

The next three sections discuss, in sequence, the differences between general and partial equilibrium models of the pollution haven effect (or leakage), the recent econometric literature on the PHH, and the recent simulation literature on carbon leakage. I have chosen this restricted focus to avoid excessive superficiality, but the cost is the absence of many important topics, including invasive species and other collateral effects of trade, the role of trade in either damaging or protecting biodiversity, the trade and foreign investment disputes related to the environment, and a broader consideration of trade and environment policies.

2. A BRIEF LOOK AT THE THEORY

The explanation for the pollution haven effect is straightforward in a partial equilibrium setting, but less so in a general equilibrium setting. This section explains the general equilibrium complications and then considers whether the partial equilibrium setting tends to understate or overstate the pollution haven effect, relative to a general equilibrium setting.

In a partial equilibrium setting, domestic demand and supply, $D(p)$ and $S(p;\tau)$, are functions of the commodity price, p. The domestic supply also depends on environmental policy, which for the purpose of exposition we can think of as being a pollution tax, τ (although of course actual policies are much more complex). The partial equilibrium setting holds other prices and income fixed. The import demand is the difference between domestic demand and supply, $M(p;\tau) = D(p) - S(p;\tau)$.

The pollution tax affects import demand only via its effect on supply in the partial equilibrium setting in which production creates the pollution. If the supply function is given by the industry marginal cost function, and if a higher tax increases marginal costs, then the higher tax shifts in the domestic supply function, increasing the domestic autarchic (no-trade) equilibrium price, and shifts out the import demand function.[1] This comparative statics experiment holds ROW environmental policy fixed. The higher tax leads to increased imports of the dirty good, to increased production of that good, and to higher

[1]A higher tax may lead to a change in the method of production, which may lead to a reduction in a firm's short-run marginal production costs, shifting out the short-run industry supply function. However, taking into account adjustment of factors, e.g., entry and exit of firms, the higher tax increases industry marginal costs.

pollution in ROW: the pollution haven effect. Exports are negative imports, so this description applies to both importers and exporters of the dirty good.

In the partial equilibrium setting, there are two links to the chain of causation. The higher tax shifts in domestic supply, and this shifts out domestic demand for imports. Either or both of these links may be broken in a general equilibrium setting. In particular, a higher emissions tax may not increase the equilibrium autarchic (relative) price of the dirty good; thus, the higher tax may not cause an upward shift of the (relative) supply function. Even if this upward shift does occur, it may not lead to an outward shift of the import demand for the dirty good. Therefore, the higher domestic emissions tax may lead to decreased imports of the dirty good. The opposite of the pollution haven effect can occur; leakage can be negative.

To make the discussion of the general equilibrium manageable, consider the simplest case, in which there are only two types of goods, a dirty good x and a clean good y. The clean sector uses capital and labor to produce the clean good. The dirty sector uses capital and labor, producing x and emissions z. Inverting this joint production function, we can write output x as a function of capital, labor, and emissions. There is no trade in factors. The supply of capital and labor is fixed, and their prices r,w are endogenous; the level of the emissions tax, τ, is exogenous, and emissions are endogenous. Both sectors produce with constant returns to scale (CRTS), and preferences are homothetic.

These assumptions imply that, conditional on the tax, the relative demand and supply functions (i.e., the supply and demand of good x relative to good y) depend only on the relative commodity price, $p = \frac{p_x}{p_y},$ as **Figure 1** shows. This figure shows the case in which a higher tax shifts in the relative supply of the dirty good, increasing the relative autarchic price of that good. As noted above, a sensible partial equilibrium model requires that the higher emissions tax increase the autarchic price of the dirty good.

Copeland & Taylor (2003) and Krishna (2010) find that in the Heckscher-Ohlin-Samuelson (HOS) model outlined above, a higher emissions tax does increase the autarchic relative price of the dirty good. However, these authors implicitly assume that the production function of the dirty good is separable in emissions and in capital and labor. The separability assumption means that the ratio of marginal productivity of capital and labor is independent of the emissions level. This assumption may not be satisfied in

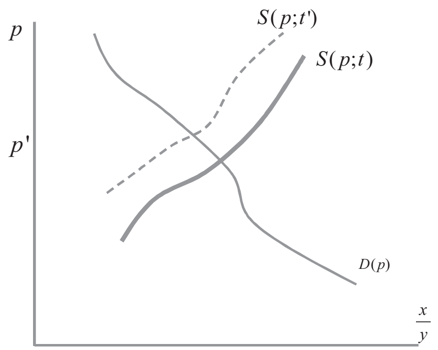

Figure 1

The relative supply and demand curves under two levels of emissions tax, $t' > t$. p' is the equilibrium autarchic relative price under t'.

reasonable circumstances. For example, an increase in environmental stringency may cause producers to shift to a more capital-intensive method of production, even at constant prices of capital and labor. In this case, the production function for the dirty good is not separable.

Separability is sufficient for an increase in the emissions tax to lead to a decrease in the relative supply of the dirty to clean goods, $\frac{x}{y}$, as in **Figure 1**; see Karp (2010) for confirmation and discussion of this and other claims in this section. Absent separability, the higher tax may shift out the relative supply of the dirty good, thus reducing the autarchic price of that good.

An example illustrates this possibility. Suppose that the clean good is relatively capital intensive and has a low elasticity of substitution between the two factors. At constant relative commodity price p, a higher tax requires an increase in the relative price of capital to labor, $\frac{r}{w}$, to maintain zero profits in both the clean and dirty sectors. Suppose also that the higher emissions tax greatly increases the marginal productivity of capital relative to that of labor in the dirty sector, to such an extent that the dirty sector shifts to a more capital-intensive production process, despite the higher relative price of capital. Denote η_{xK} and η_{xL} as the elasticity of demand for capital and the elasticity of demand for labor, respectively, in the dirty sector, per unit of output, with respect to the environmental tax. These elasticities hold the commodity price fixed but allow factor prices to adjust in response to the change in the tax; they measure a general equilibrium effect of the tax on the per-unit capital and labor requirements in the dirty sector. Denote k as the economy-wide capital-labor ratio and k_x as the capital-labor ratio in the dirty sector, with $k_x < k$ because of the assumption that the clean sector is relatively capital intensive. For a small enough elasticity of substitution between capital and labor in the clean sector, the inequality $\eta_{xK} - \frac{k}{k_x}\eta_{xL} > 0$ is necessary and sufficient for a higher tax to increase the relative supply of the dirty good. This inequality holds if the amount of labor per unit of production of the dirty good falls with the higher emissions tax, but more generally it requires that the unit demand for capital rise significantly more than the unit demand for labor, despite the higher relative price of capital.

The economic forces at work in this example are that the stricter environmental tax leads to such a large increase in the demand for capital that output in the clean sector falls by more than output in the dirty sector. A fall in output in both sectors is of course consistent with an increase in the ratio of outputs, $\frac{x}{y}$.[2]

The conclusion is that a higher environmental tax need not decrease the relative supply of the dirty good and therefore need not increase the autarchic relative price of the dirty good. The autarchic relative price equals the intercept of a country's import demand function for the dirty good. The direction of change of the import demand function (for the dirty good) is the same as the direction of change of the autarchic price in the neighborhood of the autarchic price. If the price at which the country trades happens to be in this neighborhood, i.e., if the volume of trade is negligible, then there is a pollution haven effect (leakage is positive) if and only if the higher tax increases the autarchic price. However, an increase in the autarchic price of the dirty good does not

[2]Chau (2003) provides a Cobb Douglas example in which a larger environmental tax decreases the relative autarchic price of the dirty good in the context of a model in which the number of sectors exceeds the number of factors of production. Karp (2010) generalizes this example and relates it to the result in the HOS model, described in the text.

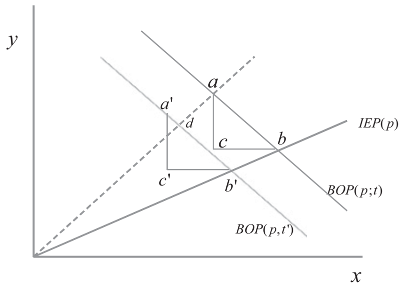

Figure 2

The balance-of-payments constraint before and after an increase in emissions tax.

imply that the import demand function shifts out for prices that are not close to the autarchic price.

Figure 2 shows a situation in which, if a country faces relative price p and an emissions tax t, the country's equilibrium production point is at a. The line labeled $BOP(p;t)$ shows the country's balance-of-payments constraint. This constraint depends on the tax because the tax affects the location of the production point, a. The line $IEP(p)$, the country's income expansion path, is a straight line because of the assumption of homothetic preferences. The consumption point is b, and the trade triangle, Δabc, shows the level of imports in the initial equilibrium as the length of the side cb, $\|cb\|$. The price p and the magnitude $\|cb\|$ are the coordinates of a point on the country's import demand function at the initial tax.

We want to know whether the higher tax increases or decreases import demand at this price. The dashed line shows the set of points at which relative production of the dirty good and the clean good equals the ratio of production at point a. If we move southwest along this line, the percentage contraction in both sectors is equal. $\frac{x}{y}$ is smaller than at point a at any point above the dashed line and is larger than at point a for points below the dashed line.

An increase in the tax, and the resulting reduction in emissions, decreases the productivity of factors in the dirty sector. The higher tax therefore reduces real income, putting aside any gains from the cleaner environment. The new consumption point must therefore lie on a lower BOP curve, e.g., on $BOP(p;t')$ at point b'.[3] By construction, the triangle $\Delta a'b'c'$ is identical to Δabc. From the property of congruent triangles, point a' must lie above the dashed line, i.e., northwest of point d.

If the actual production point lies northwest of a' [on $BOP(p,t')$], then the dirty sector has contracted more than the clean sector: The relative production $\frac{x}{y}$ has fallen. In this case, the level of imports has increased at the original price p: Imports exceed $\|cb\|$. In this situation, the higher tax has shifted out the import demand curve for the dirty good, just as in a partial equilibrium model; the pollution haven effect and leakage are positive. However, if the actual production point lies between a' and d, then the higher tax causes

[3]The production point a lies on a production possibility frontier corresponding to the initial tax. A higher tax leads to less pollution and moves the economy to a point on a production possibility frontier inside of the original one. The tax reduces the equilibrium value of production at world prices, thereby causing the balance-of-payments constraint to shift in.

the import demand function for the dirty good to shift in, leading to a negative pollution haven effect, despite that the higher tax leads to a lower relative supply of the dirty good. If the production point lies below *d*, then the higher tax increases the relative supply of the dirty good and shifts in the import demand curve, again leading to a negative pollution haven effect. Thus, a higher emissions tax may either increase or decrease the relative supply of the dirty good at the initial commodity price; a decrease in the relative supply of the dirty good is necessary but not sufficient for the tax to increase the import demand for the dirty good.

The relation between the direction of change of the (relative) supply curve and the import demand curve is ambiguous in the general equilibrium setting, in contrast to the partial equilibrium setting, in which the relation is monotonic. The ambiguity arises because the general equilibrium setting incorporates the income effect and respects the balance-of-payments constraint; both of those considerations are absent in the partial equilibrium setting.

In the HOS model, the partial equilibrium model exaggerates the pollution haven effect. In the general equilibrium setting, the higher tax induces changes in factor prices that moderate the cost increase in the dirty sector. This conclusion, however, can be overturned in a different setting, as in a Ricardian model, in which the number of commodities exceeds the number of factors (Karp 2010).

3. THE POLLUTION HAVEN HYPOTHESIS

Changes in emissions levels can be decomposed into changes associated with the scale, technique, and composition of production (and sometimes consumption). Other things equal, pollution is likely to rise with the scale of aggregate economic activity. Changes in technology and relative prices cause goods and services to be produced by the use of different techniques; cleaner techniques reduce the level of pollution. Over time, economies change the composition of goods and services that they produce, altering the level of pollution. Using 1987–2001 U.S. data, Levinson (2009) concludes that changes in technology dominate changes in both scale and composition in explaining the reduction in U.S. manufacturing emissions of SO_2, NO_2, CO, and volatile organic compounds. This article does not identify the trade-related changes in pollution.

If open economies grow more quickly than closed economies, and if environmental stringency changes with income level, trade indirectly affects pollution via income. A large literature investigates this possibility. The dominant empirical effort, however, has been devoted to trying to determine whether trade has a direct effect via the PHH. After discussing these two branches of the literature at a general level and then discussing two empirical issues that have received little attention, I focus on a particular, and exemplary, paper. This paper shows how empiricists deal with econometric problems that are endemic in this field, and it also illustrates the remaining challenges.

3.1. Income Effects

Trade is sometimes linked to the environment via an income effect. The idea is that trade promotes growth, thus increasing income, and income affects the environment, e.g., in the manner described by the environmental Kuznets curve (EKC). The EKC, an inverted-U-shaped relation between income and emissions, is based on the hypothesis that scale effects dominate in the early stages of growth: As an economy begins to develop, pollution levels rise. Higher incomes increase the demand for a clean environment, leading to stricter environmental regulation. Changes in technique and composition associated with higher income also induce the economy to switch to a cleaner mix of products and cleaner production methods, eventually leading to a lower level of pollution.

A vast literature estimates the relation between trade, and openness more generally, and growth in per-capita income. The consensus appears to be that trade liberalization promotes economic growth and enhances productivity, at least over the medium term. These results are qualified by the problems of accurately measuring trade openness and in distinguishing causation from correlation (Winters 2004).

A similarly large literature examines the relation between growth and the environment, as described by the EKC. The typical approach uses a country and time fixed effects regression of log per-capita emissions on GDP per capita and its square and other covariates, e.g., measures of governance and inequality. Early EKC studies found an inverted-U relationship for local pollutants but not for global pollutants such as CO_2. Estimates of the income levels beyond which environmental quality rises with income vary widely, even across studies that examine the same pollutant. Harbaugh et al. (2002) show the fragility of EKC estimates by reexamining the relation between income and SO_2, smoke, and total suspended particulates, pollutants for which there is the strongest evidence of an EKC. Using an extended data set and cleaning the data in a different manner than did earlier studies, the authors find that the estimated turning points change dramatically and that the inverse-U relationships can disappear. Including additional lagged values of GDP or other covariates can also significantly change estimated relations between pollution and income. Stern (2004) concludes that there is likely a monotonically increasing relation between aggregate income and pollution but that this relation shifts down over time as technology improves. van Alstine & Neumayer (2008) note the difficulty in making inferences for developing countries on the basis of the emissions history of developed countries.

The complexity and heterogeneity of the causal relations between openness and growth and between income and pollution, and the limitations of data, make it unlikely that we will be able to measure either relation with precision. Establishing empirically that openness promotes growth may be important in sustaining political support for liberal trade policies. The policy importance of measuring the EKC is less obvious. The EKC literature is careful to point out that the hypothesized negative correlation between income and pollution at high levels of income does not mean that rising income will automatically take care of environmental problems.

3.2. The Direct Effect of Policies to Control Pollution

Most of the empirical literature related to the PHH seeks to measure a direct relation between stricter environmental policies and the location of dirty-good production without attention to the trade → income → emissions channel. Early studies, reviewed by Copeland & Taylor (2004) and by Brunnermeier & Levinson (2004), found limited empirical support for the PHH. Those early studies' use of cross-sectional data made it difficult or impossible to correct biases caused by unobserved heterogeneity. Studies that examined trade patterns found that developing countries were increasingly exporting dirty goods. However, econometric analyses of the determinants of pollution typically found that openness to trade was statistically insignificantly or negatively related to pollution. Similarly, the earlier econometric analyses of plant locations and trade volumes largely found that the cost of environmental regulation was not a significant determinant of location choice or net imports.

One explanation for the lack of support for the PHH is that the costs of complying with environmental regulations account for only a small share of total production costs; these small environment-related cost differences may not create a measurable incentive to relocate production of dirty goods. The fact that most trade takes place between developed countries, with similar levels of pollution control, can also make it difficult to detect a pollution haven effect. Differences in factor endowments, technology, and infrastructure can overwhelm differences in pollution-related costs. The capital-labor ratio is of particular interest, as pollution-intensive goods tend to be relatively capital intensive; developed countries tend to be relatively capital abundant and to have stricter environmental regulations compared with developing countries. This positive correlation complicates efforts to measure the effect of environmental policy. Another explanation for the lack of empirical support for the PHH is that some major polluters are not geographically mobile because transportation costs or other factors create the need to be close to input or output markets.

Recent studies have addressed econometric problems, particularly those associated with endogeneity and unobserved heterogeneity. Attempts to deal with these problems tend to find a stronger link between environmental policy and the location of dirty-good production. The majority of these studies estimate the effect of pollution abatement operating costs (PAOCs), taken from the U.S. Census Bureau's Pollution Abatement Costs and Expenditures survey, on net imports into the United States. Ederington et al. (2005) regress U.S. net imports in 382 industries on PAOCs and find significant pollution haven effects on imports from countries with low environmental stringency and in relatively footloose industries. Using an instrumental variable estimate, Levinson & Taylor (2008) find a positive and significant relationship between PAOCs and U.S. net imports from Canada and Mexico. These and several other recent papers demonstrate that attempts to deal with endogeneity and aggregation bias frequently lead to statistically and economically significant estimates of pollution haven effects in cases in which ordinary least squares (OLS) estimates find no such evidence. To the extent that the econometric devices, usually an instrumental variable estimator, are successful in ameliorating the econometric problems, this collection of results suggests that the pollution haven effect is real and is possibly large enough to be important.

Other studies examine the effect of environmental regulation on foreign direct investment (FDI) or plant location choice. They estimate the relation between (*a*) U.S. PAOCs or measures of host country/region environmental stringency (the explanatory variables) and (*b*) U.S. FDI outflows, developing-country FDI inflows, or plant location choice (the dependent variables). Eskeland & Harrison (2003) find little support for the hypothesis that weaker environmental regulation attracts plants that produce dirty goods. Cole & Elliott (2005) conduct a similar analysis but conclude that such a causal relation exists.

Several papers estimate the relation between trade openness and concentrations or emissions of particular pollutants, most commonly SO_2. These studies also generally allow for an EKC relationship between pollutants and income by including income and income squared in the estimation equation. Frankel & Rose (2005) and Kearsley & Riddel (2010), two important papers in this branch of the literature, do not find support for pollution haven effects.

The lack of data on abatement costs in developing countries, the most likely pollution havens, is one of the most serious data limitations. This scarcity of data explains why the majority of studies use data on U.S. imports, U.S. FDI outflows, and measures of U.S. environmental regulation. Even for the United States, we do not have direct measures of the stringency of environmental regulation. PAOC is an imperfect proxy. Strict environmental regulation may drive out all but the cleanest firms in a sector, leading to a low measure of PAOC and high imports. In this case, the use of PAOC rather than an accurate measure of environmental stringency falsely contradicts the PHH.

In general, proxies for environmental stringency are likely to be correlated with the regression error. This correlation can arise because of measurement error, as described above, and because the environmental policy is truly endogenous. An increase in income or some other unobserved change may increase the level of environmental stringency (because of the greater demand for a clean environment) and increase imports of a dirty good. Concern over various sources of correlation explains recent studies' near-universal use of instrumental variables.

Several studies use proxies for environmental stringency other than PAOC; Hoffmann et al. (2005) and Waldkirch & Gopinath (2008) use emissions intensities. Kellenberg (2009) uses survey data to estimate the effect of host country environmental policy on U.S. multinational enterprise output in different countries and sectors. Other explanatory variables include host country GDP, tariffs, and intellectual protection policy. As is the case with other studies, Kellenberg's OLS estimates of coefficients on the policy variables are statistically insignificant, but instrumental variable estimates find that stricter environmental policy leads to a large and significant reduction in U.S. multinational enterprise output. Again, environmental costs do not affect output in industries that face greater limitations on mobility, including chemicals, primary metals, and utilities. Dean et al. (2009) construct data on water pollution levies in different Chinese provinces and use logit models to estimate the impact of these levies on foreign firms' plant location decisions. A foreign firm decides in which region or province to locate, conditional on its decision to invest in China. The coefficient of the pollution levy is insignificant for the sample as a whole. When the levy is interacted with a qualitative variable that measures whether the investing firm is in a low-, medium-, or high-pollution industry, the coefficient for the high-pollution industry is negative and significant, indicating the presence of a pollution haven effect.

The data availability determines the level of aggregation. This aggregation may disguise important changes in composition within an industry as defined by the data set. Ongoing research uses firm- and plant-level data in an effort to overcome this aggregation bias.

Earlier studies that used cross-sectional data were particularly vulnerable to the problem of unobserved heterogeneity. The use of panel data makes it possible to include country (or industry) and year fixed effects, which capture some of the unobserved heterogeneity, presumably reducing the magnitude of the problem. To the extent that (for example) country-specific unobserved variables change over time, the inclusion of fixed effects is an incomplete remedy. Researchers sometimes claim that (for example) country-specific unobserved variables change slowly relative to changes in measures of environmental stringency or costs. If that claim is correct—and it is not clear how it could be tested—panel data may solve much of the problem of unobserved heterogeneity.

3.3. Two Other Challenges

The econometric problems discussed above are at the core of recent empirical research. Two other issues that receive little attention are arguably equally important, but perhaps even less tractable. Most regression equations are static and fail to take into account the extent to which different observations are endogenously determined by a single large system, rather than by a collection of many small systems.

The regression equations in the above papers are either ad hoc or based on static models. Static models help to illuminate the complex medium- or long-run relations involving environmental policy and the production and trade of environmentally intensive goods. The question at the heart of the empirical literature is whether stricter environmental policies cause dirty industries to migrate. Environmental policy does not change on an annual basis, the usual timescale in empirical work, whereas PAOC and other measures of environmental stringency do change on an annual basis by construction. Even if environmental policy did change annually, adjustment costs would prevent immediate industry response. For example, if environmental policy fluctuated around a trend line, we would expect the pattern of industry growth to depend on the trend line and on possibly the variance in fluctuations. In this case, the relation between the annual level of (or change in) environmental policy and the annual growth across sectors would plausibly be small, even though the trend in regulation could be important in the medium and long run in determining the location of dirty industries. A static model's ability to pick up this medium- or long-run relation is unclear.

Every useful model is inaccurate, and it may not be helpful to criticize regression models simply because they fail to take into account the dynamic process that likely generates the data. It may still be reasonable to ask whether the regression equations are examining the relations that we actually care about.

The second problem concerns a possible disconnect between the economic question and the statistical assumptions. Suppose, for example, that we want to know whether the stricter environmental policies induced by ratification of an international environmental agreement create a pollution haven effect. We might think of this policy change as a treatment and then look for differences in, for example, net imports of dirty goods between the treated and the untreated countries—those that did and those that did not ratify the treaty. Statistical identification of treatment effects relies on the stable unit treatment value assumption (SUTVA), which is needed to be able to ascribe, to the treatment, differences in outcomes between the treatment and control groups. SUTVA states, in this context, that the level of one country's net imports of dirty goods does not depend on whether another country signed the agreement. Of course, the PHH is based on the idea that these imports do depend on trading partners' environmental policies.

Another aspect of the same problem arises when researchers use national data to examine the relation between the level of sectoral net imports and a measure of environmental stringency. Higher environmental costs in a sector reduce the value of marginal product of factors in that sector, lowering the return to these factors and/or causing some of the factors to leave the sector. In the latter case, domestic production in the sector falls and is partly replaced by imports, resulting in the pollution haven effect. The migrating factors must go somewhere. If they remain unemployed, or if they enter sectors not included in the data set, e.g., if they move from manufacturing to service jobs, then the reduced output in a particular sector need have no effect on production in other sectors.

However, if the migrating factors move into sectors that are included in the data set, then they increase production in those sectors, presumably leading to a fall in those sectors' net exports. These migration-induced effects are unlikely to be measured, so they enter the error term of the other sectors. This fact reduces the validity of instruments that use information about these other sectors.

This problem may seem trivial because only a small fraction of migrating factors would be expected to go to any individual sector. However, the aggregate effect (on estimates) of the migration may not depend on whether it is concentrated in a few sectors or is spread over many sectors. Researchers may motivate their regression equation using a partial equilibrium model, in which intersectoral migration is absent by construction. However, when the data encompass a large fraction of the manufacturing sector, it seems important to recognize that a reduction in one sector entails growth in some other sector.

Firm-level time series data may reduce the importance of these problems. One might also use Monte Carlo methods to try to obtain some insight into the importance of one or both of these problems. For example, in order to assess the ability of a static estimation model to capture the dynamic adjustment process, one could construct data using a simulation model consisting of a time trend of environmental policy and an industry-wide dynamic adjustment process that is consistent with competitive behavior. With many sectors, having possibly different adjustment processes and facing different environmental costs, the researcher could generate the type of data that are used and then see whether static estimation models can correctly identify the relations that are built into the data-generating model. (This kind of experiment has as many pitfalls as empirical work using real data and would be a risky undertaking for a researcher who cares about publication.)

3.4. A Closer Look

A detailed discussion of a single paper—particularly one that is well done and that illustrates the empirical challenges—may be more useful to someone new to this literature than a paragraph on each of many papers. Levinson & Taylor (2008), hereafter LT, build a partial equilibrium model to motivate a strategy for estimating the pollution haven effect. Each manufacturing sector, corresponding to a three-digit standard industrial classification (SIC) code, consists of many industries, each of which corresponds to a four-digit SIC code. Within a sector, the home country (Home in this discussion) imports goods produced in those industries in which trading partners' manufacturing costs are lower than Home's. In LT's application, the United States is the home country, and Mexico and Canada are the trading partners. The relative costs in a sector depend on $(c^F, \tau, c^{F*}, \tau^*)$, where c^F represents costs due to the purchase of factors of production such as labor and capital and τ is the cost of emitting one unit of pollution, e.g., a pollution tax; asterisks indicate variables for the foreign country (Foreign in this discussion).

Values of c^F, τ are constant across industries within a sector, but industries vary in environmental intensity. Within a sector, industries are indexed by η and are ranked so that a larger value of η corresponds to a more environmentally intensive industry. A given increase in τ leads to a larger cost increase in an industry with a larger index η. If $\tau > \tau^*$, i.e., if environmental policies are stricter in Home than in Foreign, then Home imports goods produced by those industries whose value of η exceeds a critical level, $\bar{\eta}$, i.e., from the dirtiest industries.

An approximation of the model yields the linear estimation equation

$$N_{it} = \beta_0 + \beta_1 s_{it} + \beta_2 c_{it}^F + \beta_3 c_{it}^{F*} + \beta_4 \tau_{it} + \beta_5 \tau_{it}^* + \varepsilon_{it}, \quad (1)$$

where N_{it} are U.S. net imports (scaled by domestic production) from sector i in period t, s_{it} is the share of expenditures on sector i in period t, and the other right-hand-side variables are as defined above but now have sector and time subscripts. The empirical challenge is that none of the right-hand-side variables are observed. There are data on sectoral pollution abatement costs, measured as a fraction of sectoral value added; LT denote this ratio as θ_{it}. The variables $(c^F, \tau, c^{F*}, \tau^*)$ determine the critical index, $\bar{\eta}$, and therefore determine the set of industries that operate in a particular sector in Home. Therefore, θ_{it} depends on all four variables.

Due to the missing data in Equation 1, LT estimate

$$N_{it} = a\theta_{it} + bT_{it} + \sum_{i=1}^{N} c_i D_i + \sum_{t=1}^{T} d_t D_t + e_{it}, \quad (2)$$

where T_{it} is a measure of trade restrictions and D_i and D_t are sector and year dummies. The goal is to determine the effect of Home's environmental policy on its net imports, but the only explicit measure of abatement costs, θ, also depends on other variables. An OLS estimate of the parameter a tells us the relation between pollution abatement costs and net imports but has little to say about the causal relation between the stringency of environmental policy and net imports. The inclusion of time and sector fixed effects in the regression in Equation 2 accounts for time-varying changes that are constant across sectors and for sector-specific differences that are constant over time.

LT identify several types of econometric problems. Omitted variable bias arises from the absence of measures of (c^{F*}, τ^*), which are correlated with the included variable, θ_{it}. Consider two sectors in Home with identical values of (c^F, τ) and identical abatement technologies, and assume that Foreign sector 2 costs are lower than Foreign sector 1 costs. Home therefore imports a larger range of sector 2 industries relative to sector 1 industries. The critical value $\bar{\eta}$ is lower for sector 2 than for sector 1. Compared with sector 2, sector 1 therefore includes a dirtier range of industries and has larger pollution abatement costs as a fraction of value added, but lower net imports. This negative correlation between θ and net imports illustrates that θ is not an adequate measure of the stringency of environmental policy.

A second type of econometric problem arises because the stringency of domestic sectoral policies, τ_{it}, increases the abatement costs of the industries operating in the sector and thereby decreases the critical level $\bar{\eta}_i$ that determines which industries in the sector operate. The higher value of τ_{it} and the resulting lower endogenous value of $\bar{\eta}_i$ have offsetting effects on θ_{it}. To the extent that stricter environmental policies drive out the dirtiest industries, a regression of net imports on the pollution abatement costs of the remaining industries will fail to detect the pollution haven effect, even though that effect may be significant.

As with much contemporary econometric research, the action lies with the choice of instruments used to deal with correlation between the error and the regressors. The inclusion of the fixed effects means that the instrument must vary over both time and sector. The regressor θ_{it} depends on $\left(c_{it}^F, \tau_{it}, c_{it}^{F*}, \tau_{it}^*\right)$, but the variable of interest is τ_{it}. The objective is to find instruments that are correlated with θ_{it} but not with $\left(c_{it}^F, c_{it}^{F*}, \tau_{it}^*\right)$ because the latter variables enter the error term. LT note that environmental policy differs across states and that sectors are not uniformly distributed across states.[4] Consequently, some sectors are concentrated in states with relatively strict regulation.

LT use this variation to construct instruments. They look for state characteristics that are strongly correlated with state-level regulation and thus with state pollution abatement costs. Given such a characteristic, q_s for each of the 48 contiguous states, s, they construct the following instrument for θ_{it}:

$$\varsigma_{it} = \frac{\sum_{s=1}^{48} q_{st} v_{is}}{v_i},$$

where v_{is} is sector i's share of value added in state s in 1977 and v_i is the sum over s of these shares. The data cover 1977–1986. A change in the unobserved c_{it}^F, for example, might change the value added in sector i in year t. The use of 1977 rather than contemporaneous value-added weights prevents this kind of relation from causing the instrument to be correlated with the error.

LT's choice of q_s is guided by the principle that factors that affect society's willingness to tolerate pollution (the supply of pollution) and factors that affect industry's desire to pollute (the demand for pollution) are correlated with the equilibrium level of regulation in a state. For the supply-side variable, the authors choose income per capita in state i in year t. The rationale for this choice is that a higher level of income may be associated with a higher demand for a clean environment and thus with stricter environmental standards. Over a long time period, this relation is plausible. It is not obvious, however, that we should expect the stringency of environmental regulation to reflect year-to-year variations in income. Without a substantial relation of this sort, the efficacy of the instrument is questionable.

To capture the demand side of the environment, LT use actual levels of 14 types of emissions. Here, the state characteristic has an industry index. For a particular type of emissions, e.g., airborne particulates, E_{jst} is the level of emissions from sector j, state s, and year t. The industry/state/year characteristic is

$$q_{ist} = \sum_{j \neq i} E_{jst}, \tag{3}$$

which equals the level of this particular pollutant in state s in time t due to industries other than industry i. Sectors that are concentrated in states where emissions from other sectors are high have large values of q_{ist}. The authors note that if sectors other than i face a shock that causes them to increase production and emissions, q_{ist} increases; they conclude that this shock "shifts pollution demand to the right, and raises [pollution abatement costs] for the i'th sector." Presumably the causal relation is that at the initial level of regulation, the shock-induced increased emissions would be socially excessive, causing an increase in the equilibrium stringency of regulation and an increase in abatement costs of the ith sector. Again, it is unclear whether a shock in period t that increased other sectors' pollution at a given level of regulation would affect the regulation that sector i faced in period t.

LT state that the validity of their instruments relies on the following small-industry assumption: "Sector specific shocks to costs, tariffs, foreign pollution regulation etc., that alter home sector production are not large enough to induce a change in the stringency of environmental policy in the states in which this sector resides." This assumption, together with the passage quoted in the previous paragraph, means that, although shocks

[4]It would be interesting to have evidence of the relative importance of state and federal environmental regulations in determining pollution abatement costs.

in sector i do not affect the stringency of environmental policy facing the sector, shocks in a group of sectors other than i do affect that stringency.

The basis for the claim that this assumption validates the instruments is unclear to me. Consider the following analogy, in which we have time series data on prices and quantities and we estimate a supply equation with quantity on the left side; in this case we know that price is likely correlated with the error term. We may try to resolve this problem by moving to panel data, for which in each year we have observations on quantities from many different sources, all selling in the same market at approximately the same price. It might be tempting to argue that, although aggregate quantity in a year does affect price, the quantity from any one of the sources has a negligible effect on price (a version of the small-industry assumption). With this reasoning, the disaggregation appears to at least alleviate the endogeneity problem. However, the aggregate shock affecting aggregate supply is composed of the individual shocks affecting individual supply, and the aggregate shock is correlated with price.

The consequence of disaggregation is easiest to see if we take the extreme (but intrinsically uninteresting) case, in which $q_{it} = a + bp_t + e_{it}$, which under OLS yields the same parameter estimates as $q_t = a + bp_t + e_t$, with $q_t = \sum q_{it}$. Moving to a finer level of disaggregation, in which the shock for any individual observation has a negligible effect on the regressor, does not alleviate the endogeneity problem.

LT note that their instruments fail if "any single sector can have a significant effect on the aggregate demand or supply of pollution." My point is that the instruments may fail even if only the collection of sectors (rather than a single sector) has a significant effect on the aggregate demand or supply of pollution. Many environmental policies affect a broad swath of sectors. Even if conditions in a single sector are not powerful enough to affect those policies, aggregate conditions likely do affect the policies (if one puts aside the issues about the temporal relation described above) and therefore affect pollution abatement costs in many of the sectors.

Through the use of the assumption of CRTS and a partial equilibrium setting, the sector-specific costs, c^F, are exogenous. If all factors were literally sector specific, then an increase in environmental stringency in a sector would lead to a reduction in the rent to the sector-specific factors; there would then be no decrease in output and no change in imports except that caused by changes in demand induced by changes in income. Of course, there is some mobility of factors across sectors, as noted in the previous section. At constant factor prices, the decreased use of environmental services due to stricter policies (likely) decreases the marginal productivity of mobile factors, causing them to exit the sector located in states where policies have become more stringent; the decrease in mobile inputs augments the decline in output caused by the lower use of environmental services. As these factors move into sectors less affected by environmental policies, production in those sectors increases, and (if one ignores income effects) net imports there fall. To the extent that the migration in factors is associated with a fall in these factor prices, the growing sectors absorb additional factors.

Consider the effect of a shock in period t to a group of sectors, excluding sector i, that causes those sectors to release factors, some of which enter sector i. Even if this change has no effect on sector i's pollution abatement costs via the demand-for-pollution mechanism described above, the absorption of factors causes N_{it} to fall. The fact that the shocks are not observed means that they enter the error e_{it}. However, the shocks affect q_{it} defined in Equation 3. Thus, the instruments are correlated with the errors. This relation arises because factors that leave one sector must enter other sectors or the pool of unemployed. Provided that a significant fraction of the factors that are released from a sector find employment in other sectors included in the data set, the problem described here arises.

There is no such thing as the perfect instrument. The point of this discussion is to explain how leading researchers in this field construct instruments in an attempt to reduce the endogeneity problem. The view that some important problems remain unresolved does not diminish the value of their effort. As noted above, instrumental variable estimators find statistically and economically significant evidence of the pollution haven effect when OLS estimators do not.

4. CARBON LEAKAGE

Carbon leakage is a particular example of the pollution haven effect. Because few nations have experimented with meaningful carbon limitations, we do not have the kind of data that have been used to estimate other types of pollution haven effects. Most of the literature on this topic therefore uses simulation models to estimate likely magnitudes of carbon leakage and the effects of trade policies.

Mattoo et al. (2009) produce leakage estimates of approximately 3.5% in a scenario in which, by 2020, high-income countries reduce carbon emissions by 17% relative to 2005 levels [equivalent to an estimated reduction of 28% relative to business as usual (BAU)]. The authors argue that leakage is small because exports account for a small proportion of low- and middle-income country production of carbon-intensive goods and because the expansion in the export sectors draws resources out of less carbon-intensive sectors, reducing production and emissions in those contracting sectors. The authors also estimate leakage in a simplified model that allows them to do Monte Carlo studies. In this exercise they find average leakage of 11%, a much larger level than the point estimate of their full model.

They find that a border tax adjustment (BTA, i.e., an import tax or export subsidy) based on the carbon content embodied in imports causes a significant decrease in exports from China and India and an increase in EU production, leading to negative leakage. This policy lowers developing-country welfare because it reduces the price that developing countries receive for their exports. A BTA on imports and exports based on the carbon intensity of production in the high-income (regulated) countries leads to zero leakage and to a smaller loss in developing-country welfare.

Fischer & Fox (2009a,b) use both a computable general equilibrium (CGE) model and a partial equilibrium model to estimate leakage, and they provide formulae for leakage under different policy scenarios. For a scenario with a \$50 ton^{-1} price on carbon emissions, Fischer & Fox's partial equilibrium estimates of leakage rates range from 60% in the oil and steel sectors to approximately 10% in the electricity sector and in the paper, pulp, and print sector. The authors point out that much of this leakage is attributable to energy price changes and cannot be controlled by border adjustments or rebates. Because energy is a factor of production, the effect of its price change would be excluded from most partial equilibrium analyses. The authors therefore calculate marginal leakage, defined as the change in the foreign sector's emissions induced by production price changes in that sector (rather than by energy price changes). Their estimates of marginal leakage rates range from 57% for the oil sector to 2% for the paper, pulp, and print sector. A BTA based on foreign emissions intensity generates only an additional 8% reduction in net emissions relative to the carbon tax alone in the oil sector; the emissions reduction induced by the BTA is smaller for other sectors. Fischer & Fox's CGE estimates of leakage are 28% for energy-intensive manufacturing and 14% overall.

The contrast between Mattoo et al. (2009) and Fischer & Fox (2009a) is striking. The emissions reduction in the former paper is supported by a \$241 ton^{-1} carbon tax, and the tax in the latter paper is \$50 ton^{-1}. To the extent that leakage depends on the size of the emissions reduction in regulated countries, I would expect stricter regulation to increase leakage, but comparison of the papers shows the opposite, with a large difference in estimated levels of leakage. The two papers have important modeling differences, but they address the same policy question and on that basis should be comparable.

Babiker (2005) argues that prior estimates of leakage are downwardly biased due to model assumptions that limit the ability of industries to relocate in response to environmental regulation. In his model, fossil fuels producers face decreasing returns to scale and perfect competition; perfectly competitive firms use CRTS technology to produce electricity and non-energy-intensive tradable goods. However, energy-intensive tradable goods are produced under imperfect competition and with increasing returns to scale (IRTS). He estimates the leakage arising from emissions constraints in the OECD and the former Soviet Union consistent with the Kyoto Protocol under several sets of assumptions about market structure. He finds a large shift in the energy-intensive industry out of the OECD. The model produces leakage estimates ranging from 25% with IRTS and differentiated products, to 60% with CRTS and homogeneous products, to 130% with IRTS and homogeneous products. The conclusion is that if IRTS and product homogeneity are accurate representations of energy-intensive industries, at least in the long run, then unilateral climate policies may lead to higher global emissions.

Burniaux & Martins (2011) describe the channels through which carbon leakage can occur. In the energy markets channel, a reduction in demand for carbon-intensive fuels by countries with carbon constraints causes a fall in the world price of these fuels. Lower fuel prices increase the quantity of fuel demanded in unregulated countries and can lead to an increase in global emissions. The structure of energy markets is important here; fuel markets must be integrated and fuel supply must be somewhat inelastic for leakage to occur through this channel. Changes in energy prices can also lead to negative leakage if emissions constraints imposed by the Kyoto Protocol cause a fall in the price of oil relative to that of coal. That change in relative price can cause some countries, including China, to substitute away from coal and toward oil. The non-energy-markets channel is the pollution haven effect discussed above: Carbon emissions pricing leads to decreased domestic production of carbon-intensive goods and to substitution toward goods produced in unregulated countries. This shift in global production toward countries that do not have emissions constraints, and that frequently have more carbon-intensive methods of production, can result in increased global emissions. Capital may also relocate to the unregulated countries, again increasing global emissions.

To assess the importance of the different leakage channels, Burniaux & Martins (2011) conduct sensitivity analysis using a simplified two-country, two-good, three-fuel (oil, coal, and low-carbon) framework, which was calibrated to mimic a larger CGE model. They seek to explain the 2–21% range of leakage estimates produced by a group of earlier models. They find that the non-energy-markets channel has little impact on leakage, as leakage remains below 4% over the full range of parameters tested that affect this channel. They conclude that Armington substitution elasticities and the migration elasticity of capital are not key determinants of the magnitude of leakage. In the energy markets channel, the key parameter is the supply elasticity of coal; lower elasticities lead to higher levels of leakage. For elasticities between zero and two, the estimated leakage rate can exceed 20%. The value of this elasticity has not been precisely estimated, but over the range of values often used in the literature, the leakage rate is small.

McKibbin & Wilcoxen (2009) use a CGE model to estimate import tariffs that would result from BTAs on imports into countries that have a carbon tax, from countries where carbon emissions are unconstrained. They also examine the extent to which leakage estimates depend on relative carbon intensities of production between importing and exporting countries. If the EU uses a carbon tax starting at \$20 ton^{-1} and rising to \$40 ton^{-1} over 40 years and uses a BTA based on U.S. carbon intensity, the effective tariffs are below 1% for tradable goods other than fuels. If the United States uses this carbon tax and imposes a BTA based on China's carbon intensity, the effective tax rises to 4%. Absent a BTA, the EU carbon tax leads to 10% leakage; adding the BTA to the carbon tax leads to negative leakage. Absent a BTA, the U.S. tax leads to 3–4% leakage; including the BTA again causes negative leakage. These results suggest that effective tariffs are small for most goods at moderate carbon tax levels. In view of the small level of estimated leakage, the authors conclude that the modest environmental benefits of BTAs do not justify their efficiency cost and administrative complexity.

Several studies, including Demailly & Quirion (2008), Ponssard & Walker (2008), and Ritz (2009), use partial equilibrium models of specific sectors. Their estimates of carbon leakage are at the high end of the range of estimates produced by general equilibrium models. Karp (2010) uses an analytic partial equilibrium model to show how key parameters affect the magnitude of leakage. These parameters include supply and demand elasticities, the elasticity of output with respect to the carbon constraint, and the elasticity of unconstrained emissions with respect to output. This model also shows why a BTA that fully compensates producers in carbon-constrained countries for the additional environment-related costs results in negative leakage. The equilibrium BTA is an export subsidy; it increases domestic consumer prices in the constrained countries, leaving domestic producer prices equal to world prices. Some of the general equilibrium models discussed above also find that a BTA results in negative leakage.

5. CONCLUSION

Most of the effort in the field of trade and the environment during the past several years has gone to assessing the likely magnitude of the pollution haven effect. The econometric literature has tried to move from establishing correlation to causality, using instrumental variables. A robust finding is that instrumental variables show stronger evidence of a measurable pollution haven effect compared with OLS estimates. Data availability constrains our ability to construct valid instruments, a problem that may diminish with the use of more disaggregated data. It is uncertain to what extent static models, which look at contemporaneous relations between levels or changes in production or imports and changes in proxies for environmental policy, are able to capture what may be a dynamic relation. The degree to which the interconnectedness of markets, e.g., general equilibrium effects, weakens the validity of instruments, making causality harder to establish, is also unclear.

Carbon leakage is an example of the pollution haven effect writ large. Given the absence of historical experience with meaningful carbon restrictions, we do not have data to do the kind of empirical work used to estimate the pollution haven effect for other pollutants. Researchers therefore use simulation models, often CGE models, to estimate the extent of carbon leakage and the effect of trade policies to mitigate leakage. The literature disagrees about the magnitude of carbon leakage, and therefore about the future importance of trade policies, in the event that nations begin to adopt meaningful carbon restrictions. My view is that there is more to be gained by estimating the parameters of partial equilibrium models for a small number of carbon-intensive commodities, relative to building ever more elaborate CGE models. In the HOS model, factor price changes moderate the cost increases due to stricter environmental policies and thereby reduce the amount of leakage. In comparison to these models, a partial equilibrium estimate is likely to produce a higher estimate of the magnitude of leakage; this result, however, is not robust to changes in the general equilibrium model.

Economists are broadly skeptical about the wisdom of using trade policies to address environmental problems. For local pollutants, the principle of targeting remains a good guide to policy. I think that the prescription is different in the case of transboundary externalities such as carbon emissions, particularly when we know so little about the magnitude of leakage. In this case, I support the judicious use of border tax adjustments, but many economists think that they are likely to do more harm than good. Economists have a valuable role in helping to design these policies, largely as a means of offsetting the risk of disguised protectionism. Trade policy can also play an important role in protecting endangered species and endangered habitats.

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