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International Trade and Green Growth

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Abstract

This paper reviews the challenges and opportunities raised by international trade for developing countries considering a green growth strategy. A key concern is the effect of environmental policies on international competitiveness. For production-generated pollution, there is evidence that stringent environmental policy reduces some indicators of competitiveness, but the effect is small in most sectors. However, tightening up environmental standards is unlikely to reduce international competitiveness when pollution is generated by consumption. And where depletion of natural capital is a threat, effective environmental policy is an important component of a policy aimed at developing long-run international competitiveness.

The effects of trade on environmental policy, the interaction between trade and technology transfer, and the interaction between trade and transboundary environmental problems are also reviewed. An emerging issue is the potential use of border taxes to curtail carbon leakage. The paper discusses some of the possible responses by developing countries. Some work has indicated that export taxes or voluntary export restraints applied to carbon-intensive production in non-coalition countries may be preferable to a carbon tariff regime. The paper concludes by suggesting some topics for further research.

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International Trade and Green Growth*

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1. Introduction

This paper reviews some of the challenges and opportunities raised by international trade for newly industrializing countries considering a green growth strategy.

One of the main deterrents to adopting fully efficient environmental policies is concern about the effects of such policies on international competitiveness in the manufacturing sector. This is often characterized as a trade-off between income and environmental quality. From the perspective of a newly industrializing country, the issue is whether growth in a competitive world economy is dampened by effective environmental policy.

There has been extensive research on this issue, most of which uses data from OECD countries. This work is reviewed in section 2 of the paper. In many sectors there is either no trade-off between international competitiveness and environmental policy, or at best a short run trade-off. For pollution that is generated by consumption (such as from automobiles or home heating), tightening up environmental standards does not reduce international competitiveness, and in some cases may promote local firms at the expense of imports. This is because emission standards targeting consumption-generated pollution apply to imports as well as local production and do not place domestic industry at a cost disadvantage. Moreover, high emission standards may yield long term export benefits by encouraging local industry to develop the expertise to build products that meet emission standards in foreign markets.

For environmental problems that lead to the depletion of natural capital, such as deforestation, fisheries depletion, soil erosion, or toxic emissions that harm human health, weak environmental policy may yield short run income gains but long run income losses. In such cases, effective environmental policy is an important component of a policy

aimed at developing long run international competitiveness. These and other issues involving natural capital are touched on in section 2 of the paper and discussed in more depth in section 5.

For production-generated pollution that does not have significant effects on income-generating natural capital, there is evidence that tightening up environmental policy does have a negative, albeit usually small, effect on indicators of international competitiveness such as net exports or new investment in the relevant sector. Most of this evidence comes from OECD countries and there is very little evidence on the effects in developing countries. On the other hand, the literature on the pollution haven hypothesis has found little or no evidence that pollution intensive industry is systematically migrating to jurisdictions with weak environmental policy; hence maintaining a weak environmental policy regime appears to have little effect on a country's comparative advantage. Other factors such as labor productivity, capital abundance, and proximity to markets are much more important in determining firm location and output.

Concerns about competitiveness also influence the structure of environmental policy, an issue discussed in section 3 of the paper. There is political pressure for differentiated environmental policies; that is, for policies that shelter the tradable sector from stringent regulation. While there is some evidence that many governments do this, there is little evidence on whether or not such policies increase economic growth rates.

A useful way to think about this issue is to realize that weak environmental policy is effectively a subsidy for pollution-intensive production and to ask when it might make sense to subsidize or promote some sectors at the expense of others. If there are learning spillovers and agglomeration effects, there can be efficiency arguments to promote some types of economic activities; however it is unlikely that weak environmental policy would be the most effective instrument to achieve this end. The literature on international competitiveness has found that environmental policy has relatively small effects on

indicators such as net imports or exports. Hence weak environmental policy is not a particularly effective tool to use to promote nascent import-competing sectors. Moreover if the motivation for an industrial policy is driven by factors such as learning spillovers or agglomeration effects, then it is better to use policy instruments that target those issues directly.

Access to green technology is essential for green growth. One important issue is whether newly industrialized countries can "leapfrog" past developed countries and quickly move to the frontier of green technology. There is considerable evidence that the speed of diffusion of technology across borders has accelerated in recent years. There is also considerable evidence of "lock-in" effects for technologies – there are often long lags in the adoption of new technologies that are caused by factors such as the skill set of workers, network effects, and infrastructure. These issues can lead to conflicts between the goals of long and short run competitiveness. In the short run, it may be more cost effective to go with older pollution-intensive technologies. But with lock-in effects, failure to provide incentives for the adoption of greener technologies can increase long run costs. Section 4 of the paper reviews these issues.

Finally, many environmental problems are transboundary or global in scope. As discussed in section 6 of the paper, international trade is becoming central to this issue. Trade instruments are frequently cited as candidates for enforcement tools for international environmental agreements. Moreover, in the context of climate change, concerns about carbon leakage have increased the likelihood that some form of border taxes may be imposed on imports of carbon intensive goods from countries that do not join a coalition to reduce emissions. Several studies have found that border taxes would mitigate carbon leakage, but that the major consequence of such policies would be to shift some of the costs of emission reductions from developed to developing countries via terms of trade effects. While on the one hand, developing countries can object to border taxes on these and other grounds; on the other hand, major emission reductions may not

be politically feasible in developed countries without some mechanism to deal with leakage. It is therefore useful to consider alternative policies that achieve this objective. Export taxes or voluntary export restraints applied to carbon-intensive production, for example, are likely to be preferable to an import tax-based regime.

The concluding section of the paper provides a brief discussion of directions for future research.

2. Effects of environmental policy on international competitiveness

Openness to trade is often viewed as a double-edged sword when thinking about economic growth. Exports are a powerful engine of growth, but competition from foreign producers can displace local production. This leads to pressure for policies that favor exporters and protect import-competing firms. International trade agreements constrain some policies of this type; however the pressures on governments to shelter firms from foreign competition remain and may even be magnified by trade agreements. This heightens the temptation to manipulate environmental policy on the grounds that it might inhibit international competitiveness.

In principle, openness to trade does not affect the case for efficient environmental policy. Weak environmental policy effectively acts as a subsidy to pollution-intensive activity. International trade does not alter this. Allowing a firm to pollute excessively is in principle no different than giving a firm a subsidy to hire labor - in each case, the subsidy shifts economic activity away from sectors in which the economy is relatively more productive to sectors that are subsidized. If there are no other distortions in the economy, an efficient policy to promote economic growth would eliminate all subsidies, including implicit subsidization of activities that degrade the environment.

Matters are more complex than this in practice. Political pressures drive governments to promote some sectors over others. There are also efficiency reasons to consider deviations from the no-subsidy rule. No economy is free from distortions and market imperfections. In newly industrializing economies some of these loom large. Access to capital may be imperfect; there are learning spillovers; there are agglomeration externalities; and competitors in both domestic and foreign markets may have market power. Any or all of these factors can encourage governments to promote exporting firms or protect import-competing firms. The issue I want to focus on here is whether, given these realities, the case for a "green growth" path is weakened by international competitiveness concerns.

A large literature considers the effects of environmental policy on international competitiveness. Much of the theoretical literature starts with the premise that tightening up environmental policy raises costs in affected sectors. However, this need not always lead to a loss of international competitiveness in those sectors. The net effect depends on whether pollution is generated during production or consumption, and on the extent to which environmental degradation destroys natural capital.

In the case of production-generated pollution, standard models predict that tighter environmental regulations drive up costs and shift supply curves inward (in the case of perfectly competitive industry) or put domestic firms at a strategic disadvantage relative to foreign rivals (in the case of imperfect competition). This is the basis of the literature on the pollution haven hypothesis. Copeland and Taylor (2004) distinguish between a weak and strong version of the pollution haven hypothesis. In the *weak* version (or what we call a pollution haven *effect*), tighter environmental policy causes some pollution-intensive production to shift to other countries (via either trade or capital flows or foreign direct investment). This prediction is quite robust and is driven by the cost-increasing effects of regulation. However, it need not imply that pollution-intensive production will relocate to countries with weak environmental policy. Those producers who decide to

move will simply seek a location that is more cost-effective. Environmental policy is only one such factor to consider – costs are also affected by many other factors such as labor costs, other government regulations, institutions, and proximity to customers. In the *strong* version of the pollution haven hypothesis, environmental costs dominate these other factors, and jurisdictions with weak environmental policy attract pollution-intensive production. This prediction is not robust, since it relies both on the cost-increasing effects of regulation, and also requires that these costs be more important that other factors influencing location choice.

If pollution is generated during consumption, then environmental policy that raises costs need not cause pollution-intensive production to relocate. It may even *increase* competitiveness of local firms.[1] This is because environmental policy aimed at controlling consumption-generated pollution (such as automobile emissions) applies to all goods used within a country: both foreign and domestically produced goods have to meet the same emission standards. Consequently, tighter standards raise costs for both domestic and foreign producers and hence domestic firms need not be disadvantaged. The effect on the competitiveness of domestic firms depends on how the cost of complying with tighter regulations varies across producers. If it is cheaper for domestic firms to comply than foreign firms, then local production can increase as a result of tighter environmental standards.

The Porter Hypothesis questions the premise that more stringent environmental policy raises costs (at least in the long run). Porter and van der Linde (1995) argue that appropriately designed environmental policy can increase an industry's international competitiveness either by inducing managers to reduce waste and use resources more efficiently, or by stimulating innovation.[2] The hypothesis is often criticized because a narrow interpretation might suggest that it relies on the assumption that (prior to

[1] See McAusland (2008) and Copeland (2011).

[2] See Ambec at al (2011) for a recent review of the literature on the Porter Hypothesis.

regulation) firms ignore potential cost-reducing or profit-enhancing opportunities. If firms really would be more competitive if they reduced their emissions, why do they need to wait for regulators? Some subsequent theoretical work showing how the hypothesis can be valid relies on models with organizational failure so that managers' incentives are not correctly aligned with firm profitability (see for example Aghion et al., 1997). Other work relies on market failures, such as externalities in the innovation and technology adoption process. Mohr (2002) develops a model where an environmentally friendly technology exists that is potentially less costly than the existing technology. Firms do not adopt the new technology because there are learning spillovers; that is, the existence of positive externalities in the adoption process leads to an inefficient equilibrium. Regulation solves the coordination problem and in the long run both reduces pollution and increases competitiveness.[3] This line of thinking has some similarity to the infant industry argument from international trade. In that literature efficiency can be improved by promoting a nascent sector if there exist markets failures such as learning spillovers or agglomeration effects. Both the infant industry argument and Mohr's version of the Porter Hypothesis point to cases where there is an argument for an industrial policy to internalize positive externalities; in the absence of such a policy then tightening up environmental policy (in the case of Mohr) or restricting trade (in the case of the infant industry argument) can increase productivity.

Short and long run effects of environmental policy on international competitiveness can also differ if economic activity leads to a degradation of natural capital.[4] Fish harvesting is a good example of this. Open access fisheries become depleted because of harvest externalities: individual fishers lack incentives to conserve fish stocks because the benefits are spread over all potential harvesters. Regulating the fishery raises costs in the

[3] See also Greaker (2006) who develops a model where there are increasing returns to scale in the environmental services industry so that more stringent regulation lowers abatement costs and can potentially increase competitiveness.

[4] Copeland (2011) discusses the implications of natural capital for the pollution haven hypothesis, drawing especially on the work of Brander and Taylor (1997).

short run, and this reduces international competitiveness. But such regulations allow the stock to replenish and become sustainable in the long run. Hence long run competitiveness in the industry is enhanced by regulation. Similar examples include policies aimed at reducing soil erosion or managing forests on a sustainable basis. These increase short run costs but enhance long run competitiveness. A broader interpretation of natural capital would include air and water quality because of their role in affecting human health. The major benefits of improving air and water quality are reduced premature deaths and improved human health. Short run costs of more stringent environmental policy can increase long run competitiveness by nurturing a healthier and more productive labor force.

The empirical literature on the effects of environmental regulation on international competitiveness has been hampered by the lack of good international data on the stringency of pollution regulations. Consequently, much of the literature has focused on the United States because of data availability.[5] A number of papers study the effects of heterogeneity of environmental regulations across counties or states in the U.S. on plant location and incoming investment flows. Other papers study US trade flows, exploiting industry-level differences in the stringency of environmental regulation. Most of the literature focusses on the manufacturing sector, and studies production-generated pollution. There is relatively little work investigating the effects of environmental regulation on competitiveness in newly industrializing countries. And there is almost no empirical literature that looks at the interaction between trade and regulations aimed at preserving natural capital.

[5] The empirical literature on the Porter Hypothesis has been somewhat more international in scope, although mostly focussing on OECD countries. That literature studies the effects of environmental regulation on innovation, with some studies also looking at the net effect on productivity. See the review by Ambec et al. (2011). I will not discuss that work here since my focus is on international trade and investment issues.

Most work in this literature focuses on the weak version of the pollution haven hypothesis. That is, it attempts to estimate the empirical relation between some measure of economic activity (such as trade or investment flows, plant location, or output) and a measure of the stringency of environmental regulations. The key question is whether more stringent environmental regulation has a negative effect on the relevant measure of economic activity. In one branch of the literature data on interjurisdictional differences in environmental policy is used. Researchers seek to determine whether tightening up environmental policy reduces the probability of a new plant locating in that jurisdiction, decreases inward foreign investment, increases the likelihood that a firm will move its production outside that jurisdiction, or whether net exports in affected sectors fall. In another branch of the literature, data for just one jurisdiction are used, and variations in the stringency of environmental regulation across sectors are exploited. For example, some studies look at the effects of US environmental policy on net trade flows across industries.

Much of the early work [see Jaffe et al. (1995) and Levinson (1996) for good surveys] found that environmental policy had little or no effect on trade and investment flows, and in some cases more stringent environmental policy was associated with increased competitiveness, a result that was sometimes taken as evidence in support of the Porter Hypothesis. A common explanation for the finding was that in most industries compliance with environmental regulations accounts for a small fraction of costs.

However, subsequent work has focused on strategies to deal with the endogeneity of environmental policy and unobserved heterogeneity. The concern is that there will often be an unobserved (or uncontrolled for) factor that tends to both make the jurisdiction an attractive location for polluting industry and which also results in increased pressure on regulators to tighten up environmental policy. Hence one might find a spurious positive correlation between the stringency of environmental policy and international competitiveness in the affected sector. Moreover, if governments are systematically less

likely to tighten up environmental policy in sectors that are facing strong import competition, then if this is not accounted for one might falsely conclude that weak environmental policy leads to reduced international competitiveness.

Much of this recent work has found evidence in support of the weak version of the pollution haven hypothesis – that is, in many recent studies more stringent environmental regulation in the manufacturing sector has a statistically significant negative effect on various measures of competitiveness in the affected sectors. [6] For example, Becker and Henderson (2000) and several other studies have found that increases in the stringency of environmental regulations induced by the US Clean Air Act tend to reduce the likelihood that a new plant will locate in the affected jurisdiction. Keller and Levinson (2002) found that high abatement costs have a negative effect on foreign investment inflows, while Hanna (2010) found evidence that the US Clean Air Act induced some multinationals to relocate production away from affected jurisdictions. Ederington and Minier (2003) and Levinson and Taylor (2008) found that higher abatement costs tend to have a positive effect on net imports (or equivalently, reduce net exports) in affected sectors.

There are a few studies that use data from newly industrializing countries, mostly focusing on incoming foreign investment. The results here have been mixed, with most studies finding little or no evidence that environmental policy affects the pattern of investment, but with some finding a negative effect and others a positive effect. Dean, Lovely, and Hwang (2009) used data on variations across provinces in China in charges for water pollution to determine whether the stringency of environmental policy affected incoming foreign investment. They found that more stringent regulation had a negative effect on investment from ethnically Chinese source countries (Hong Kong SAR, China; Macao; and Taiwan, China) in highly polluting sectors. However, environmental policy had no statistically significant effect on investment from other countries. Eskeland and

[6] For reviews of this work, see Brunnermeier and Levinson (2004) and Copeland and Taylor (2004).

Harrison (2003) found no evidence that abatement costs affected incoming foreign investment in four developing countries: Cote d'Ivoire, Morocco, Mexico, and Venezuela. Cole and Elliott (2005) studied outbound investment from the US to Brazil and Mexico. They cite evidence that pollution intensive industry is on average capital intensive and so chose Brazil and Mexico as host countries because they have weaker environmental regulation than the US but are also relatively abundant in capital. They found some evidence that industries with high abatement costs in the US were more likely to have high outbound investment to Brazil and Mexico. Both the Eskeland and Harrison, and Cole and Elliot studies lacked data on abatement costs in the host countries and so used US abatement cost data as their measure of policy stringency. Elliot and Shimamoto (2008) studied outbound Japanese foreign direct investment to Malaysia, Indonesia and the Philippines in 10 manufacturing industries. They used Japanese abatement costs as their measure of the stringency of pollution regulations. They found no evidence that higher Japanese abatement costs increased outbound investment to any of the three host countries, and instead found that all else equal, high abatement costs in Japan had a negative effect in investment in the Philippines (contrary to the pollution haven hypothesis). As with the Eskeland and Harrison (2003) study, Elliot and Shimamoto did not have data on abatement costs in the host countries.

There is still much to learn more about the effects of environmental policy on international competitiveness in newly industrializing countries. Since much of the empirical work has been based on the experience of OECD countries, it is important to investigate potential channels through which effects may be different in a developing economy. For example, one important question is whether the competitiveness effects of tightening up environmental policy are larger or smaller in developing countries than in developed countries. On the one hand, *marginal* abatement costs could be relatively lower in developing countries because of weaker pre-existing regulation – this is the "low-hanging fruit" story. And rapidly growing economies have the advantage that it is easier to implement environmentally friendly technologies when designing and building

new production facilities than it is to refurbish existing facilities. Both of these factors would suggest that the competitiveness effects of tightening up environmental policy would not be large in developing countries. On the other hand, if there are increasing returns or learning spillovers in the abatement process, or if substantial investments in infrastructure are required, then marginal abatement costs could be higher in a developing country.[7] It is likely that the net result of these two effects would vary across pollutants and sectors; but at this stage we have little or no evidence on the issue.

The applicability of the empirical work on plant location to an international context is also open to question. For example, early studies used US state-level data and found that environmental policy had little or no effect on which state that a firm chose to locate a new plant. However, studies such as Becker and Henderson (2000) found that environmental policy does have an effect at the county level. One interpretation is that environmental policy does not have much influence on which state a firm chooses as a site for its production; but that once a state is chosen, the firm looks for a location within that state that is attractive from a cost perspective, and that at this stage environmental policy could matter. If this interpretation is correct, then the implications of studies that find that county-level regulations within the U.S. affect plant location may not have much relevance for the effects of environmental policy on international location decisions.

There is as yet very little work that attempts to test the strong version of the pollution haven hypothesis, which is that trade liberalization causes pollution-intensive industry to systematically move to countries with weak environmental regulation. Antweiler et al. (2001) calculate the elasticity of the increase in ambient SO2 concentrations with respect to an increase in openness to trade for a large set of countries. The strong version of the

[7] Another way to pose the question is to ask whether the response to pre-existing regulations has given developed countries first mover advantages in the ability to respond to more stringent environmental regulations, or whether instead the opportunities to learn from the experience of developed countries allows developing countries to "leapfrog" past developed countries by more easily adopting environmentally friendly production techniques. The leapfrogging literature is discussed later in the paper.

pollution haven hypothesis predicts that this elasticity would fall (and become negative) as per capita income rises. They found the reverse: trade tended (at the margin) to shift SO2-intensive industry to relatively high income countries with relatively stringent pollution regulation. They conjecture that the explanation for this is that SO2-intensive industry is also capital intensive, and relative capital abundance is more important for determining trade patterns in such goods than differences in environmental policy. Ederington, Levinson and Minier (2004) found that US manufacturing production has shifted towards less polluting industries. They ask whether increased openness to trade can account for this. If the pollution haven hypothesis was operative, then one would expect that the shift to cleaner production would be explained in part by the pattern of trade liberalization. However, they find that tariff reductions over the past several decades cannot account for the shift in the composition of US manufacturing toward cleaner industries. They also compared the pollution[8] embodied in US imports from developing countries to the pollution embodied in US exports during the period 1972-94. They found that US imports became cleaner relative to exports during this period, a result that is inconsistent with the strong form of the pollution haven hypothesis. Levinson (2010) restricts his analysis to air pollutants, but accounts for pollution generated by intermediate goods production (previous work estimated only pollution from final goods). He also finds that the composition of U.S. imports has shifted towards cleaner goods.

What conclusions can we draw from this literature? Perhaps the most consistent theme underlying much of this work is that it has been difficult to find support for either the weak or strong version of the pollution haven hypothesis. This in part reflects data problems, but also reflects the fact that pollution abatement costs are a relatively small fraction of overall costs in most industries. The evidence suggests that factors such as capital abundance, labor abundance, location, institutions, and agglomeration effects are more important than environmental policy in determining firm location choice and

[8] They looked at 14 pollutants tracked by the World Bank's Industrial Pollution Projection system (Hettige et al., 1995). These include several air pollutants (such as SO2 and particulates), water pollutants (BOD and suspended solids) and toxic releases.

competitiveness. Recent work (mostly based on US data) has found evidence that environmental policy does have a statistically significant negative effect on competitiveness. However, the economic magnitude of this effect tends to be small.

What are the policy implications of the finding that more stringent environmental policy does, at the margin, reduce the competitiveness of polluting industry? In one sense, this should neither be a surprise nor cause for concern. A reduction of output in a polluting industry does not imply that tightening up environmental policy is welfare-reducing. As noted above, weak environmental policy is essentially a subsidy for the use of environmental services. Removing such subsidies may shift production towards cleaner activities and this can be expected to be welfare-improving. Moreover it does not imply a loss in competitiveness for the economy as a whole; it simply leads to a reallocation of production towards cleaner activities.

Nevertheless, there may be legitimate concerns that the affected polluting industries are central to a country's long run growth strategy. In the presence of market failures relevant to the industrialization process (such as learning spillovers, agglomeration effects, and coordination problems) there can be an efficiency rationale for subsidies and other forms of government support. However, it is difficult to make the case that weak environmental policy would be either a desirable or effective way of delivering support to such industries. This is not simply because of the social costs of the environmental damage that results from such an approach. Weak environmental policy is unlikely to be effective in stimulating local production because the evidence shows that the effects of environmental policy on production and plant location are small for most industries. Moreover, weak environmental policy would not address the market failures that would justify some form of industrial policy. Other forms of support, in combination with a policy of internalizing environmental externalities, would likely be much more effective than simply leaving lax environmental policy in place.

3. Design of environmental policy in open economies

A key insight from environmental economics is that incentive-based policy instruments have efficiency advantages over command and control regulation. These results apply equally to open and closed economies. All pollution control policies work by raising the shadow price of emissions; the challenge for policy makers who are concerned about international competitiveness is to ensure that this is done in a cost effective way. Emission taxes and cap and trade programs are standard examples of policies that should achieve efficiency; but where these are not feasible, simply giving firms emissions targets and letting them choose how to meet the target is more cost effective than allowing regulators to micro-manage the abatement process. Empirical evidence, although still somewhat limited in scope, tend to support this. Isaksson (2005) found that an emission charge system for nitrogen oxides in Sweden stimulated innovation and generated significant emission reductions at very low cost. Studies such as Burtraw (1996; 2000) showed that giving electric power plants emission caps for sulphur dioxide resulted in significant cost advantages over command and control regulations because it gave firms incentives to innovate and look for the most cost-effective method to meet their targets. Moreover, Burtraw's 1996 paper shows that these savings occurred despite very little emission trading: simply giving firms the opportunity to find the least cost way of meeting a target generated significant cost savings.

International trade adds a few complexities. The case for cost-effective instruments is probably stronger in an open economy than in a closed one simply because there is more competition in an open economy. In a closed economy, the costs of more stringent environmental regulation can be more easily passed on to local consumers. This becomes more difficult as trade liberalizes and prices become less responsive to local demand conditions. Moreover, growing economies need a regulatory system that adjusts seamlessly to increased pressure on the environment. Command and control policies often favor incumbent firms at the expense of new entrants and this can inhibit growth

and indirectly reduce internationally competitiveness by raising costs for new entrants. Market-based policies such as emission charges and cap and trade systems accommodate entrants more easily as all firms are subject to the same rules and incentives.

Once we move beyond the standard competitive paradigm and consider some of the market failures relevant to the growth process in an open economy, then the picture can become more complex. In the presence of market power, agglomeration externalities, or learning spillovers there can be efficiency benefits from policies (such as subsidies) that stimulate output in affected sectors to a level greater than that which would occur in a free market. Output subsidies, however, are often neither feasible nor desirable. International trade agreements limit feasibility because they constrain the use of some types of subsidies. Subsidies may also be undesirable because of government financing constraints, administrative costs, and potential for corruption and rent-seeking in the allocation process for subsidy disbursement.

In this context, policies such as emission taxes or emission caps on firms may sometimes be viewed as undesirable because of their output-reducing effects. Pollution taxes aimed at the manufacturing sector work to reduce emissions both by reducing the emission intensity of production and by reducing output of polluting goods. If the output effect is undesirable because of other market failures, then policies such as emission intensity standards can be a useful alternative. An emission intensity standard is a requirement that emissions per unit output not exceed some target. If there are no other distortions in the economy, an emission intensity standard is not cost effective because it is equivalent (except with respect to revenue and tax incidence) to an emission tax combined with an output subsidy. This is because an intensity standard can be met by either reducing emissions for a given output level, or by increasing output for a given emissions level (or some combination of both). In the absence of other distortions, the output-enhancing effect of the policy is efficiency-reducing. But in cases such as those discussed above where there is an argument for an output subsidy, an emission intensity standard is

attractive. It is an incentive-based instrument in that it creates incentives for firms to find the least cost way of meeting the target, and yet it also has an output-stimulating component that can be useful if one is concerned about competitiveness issues. Holland (2009) shows how emission intensity standards can be welfare-enhancing relative to emission taxes in the presence of market power;[9] similar arguments also apply to situations where there are external economies of scale, learning spillovers, or other agglomeration effects.

An R&D subsidy for green technology is another incentive-based environmental policy that can be efficiency-enhancing when there are market failures in innovation or in the environmental services sector. The argument is not much different than that for any type of innovative activity in the economy: if there are coordination failures or spillover effects that are not internalized, then subsidies or other forms of industrial policy can increase welfare. The linkage between environmental policy and green innovation policies is reviewed in Jaffe et al. (2005). In a recent paper, Acemoglu et al. (2009) have argued that subsidies for innovation are an essential component of a move to a greener growth path because of spillover effects in the innovation process.

An important policy design issue is whether the tradable sector should be sheltered from the effects of environmental policy for competitiveness and economic development reasons. In theory, an efficient pollution regulation scheme should ensure that the shadow price of emissions for a polluter reflects the marginal damage caused by its pollution. In practice, governments often use differentiated emission regulation schemes in which the tradable sector faces less stringent regulation than the non-tradable sector.[10] The question I want to pursue here is whether there is an efficiency rationale for such a strategy.

[9] Holland (2009) also shows how emission intensity standards can be useful in the presence of leakage. I discuss this later in the paper in the section on global pollution.

[10] For evidence from the US, see for example Ederington and Minier (2003).

The literature has identified several rationales for differentiated emissions policy. Many of these arguments rely on either political economy or rent-shifting arguments. Anger et al. (2006) develop a lobbying model that predicts differentiated emission taxes based on factors such as trade exposure. They find empirical support for the model using data from Germany. A large literature notes that governments have an incentive to manipulate environmental policy to improve their terms of trade or to give domestic firms a strategic advantage over foreign firms. These are rent-shifting arguments. Rauscher (1994) shows how this leads to differentiated pollution taxes across the tradable and non-tradable sector. One weakness of this approach is that governments have many instruments available to support domestic firms and if they do choose to engage in terms of trade manipulation, it is not obvious that environmental policy would be either a desirable or effective instrument (the theoretical literature resolves this difficulty by assuming no other instruments are available).

Another branch of the literature shows that differentiated emissions policy can have a role to play if pollution is transboundary and there are concerns about leakage. Most of this literature is driven by concerns about carbon leakage; i.e. that tightening up environmental policy in one country will encourage carbon intensive production to relocate to other countries. Hoel (1996) demonstrated how differentiated carbon taxes could mitigate carbon leakage.

Perhaps the most common rationale for a differentiated emissions regulation is to deal with concerns about the effects of regulation on international competitiveness. As discussed earlier, even if environmental regulation does affect the international competitiveness of an industry, this does not in itself yield an efficiency argument for sheltering the industry from environmental policy: countries have a choice of growth paths, and weak environmental policy provides an implicit subsidy to a less green growth

path. Moreover, the empirical evidence suggests that the international competitiveness effects of environmental policy are small.

If there exist other market failures in the economy, such as learning spillovers and agglomeration effects, then there can be a rationale for policies that promote some industries at the expense of others – that is, for some form of industrial policy. However, in such cases, it is unlikely that weak environmental policy would be the appropriate instrument, and it is unlikely that such market failures would apply exclusively to the tradable sector.

There are, however, a couple of arguments for differentiated emission policy that rely on the existence of other distortions in the economy. Richter and Schneider (2003) consider an economy with distortions in the labor market and show that second-best optimal emission taxes on the industrial sector are lower than on the household sector (home heating). This is because emissions taxes exacerbate distortions in the labor market.[11]

Copeland (2005) considers economies with distortions directly linked to the abatement process and develops a model where productivity in pollution abatement is endogenous and affected by the stringency and structure of pollution policy. Abatement is provided by an environmental services sector. A larger demand for abatement services supports more specialized producers and this reduces abatement costs. That is, there are effectively external economies of scale in abatement. The first best policy is a subsidy to promote expansion of the abatement sector, but if a subsidy is not feasible or does not fully internalize the spillovers, then a second best policy is differentiated emission policies. Emission taxes both directly target pollution but also indirectly promote the expansion of the abatement sector. In particular, it is shown that second best emission taxes are higher in the non-traded sector than in the tradable sector. This is because

[11] Labour supply is too low because of an income tax or some other distortion, and emission taxes can reduce labour supply even more.

domestic output tends to fall less in response to emission taxes in the non-traded sector than in the tradable sector; and therefore (all else equal) the expansion of the abatement sector is promoted more by taxing pollution from non-tradable production than from tradable production.

4. Technical change, technology transfer and trade

The main deterrents to adopting more stringent environmental regulations are concerns about compliance costs and the ensuing potential adverse effects on international competitiveness and the economy's growth rate. Consequently facilitating access to environmentally friendly technology is an essential part of an effective and efficient environmental policy. In their study of cross country technology adoption, Comin and Hobijn (2004) note that rich countries tend to be the first to adopt new technologies, although the process of adoption often occurs with long lags after innovation. Then, new technologies are gradually adopted by other countries. Technology diffusion across countries is therefore critical for new industrializing countries wanting to develop along a green growth path.

There is a large literature on technology diffusion, although relatively little work on cross-country diffusion of environmental technologies.[12] Since my focus is on trade in this paper, I will discuss only some of the trade-related issues related to diffusion and innovation. Evidence suggests that openness to international trade and foreign direct investment are among the key factors (others include per capita income and education) that are correlated with adoption rates for new technologies. In some cases technology diffuses directly via trade and investment: some technologies are embodied in capital goods; some are knowledge-based and diffuse via movements of personnel attached to multinational firms; and some can be copied by studying imported goods that exploit new

[12] Keller (2004) reviews the literature on international technology diffusion. On environmental technology, see section 4 of Popp et al. (2009), part of which reviews the literature on diffusion of environmentally friendly technologies across countries.

technologies. Trade also has indirect effects on technology adoption via market pressures: domestic firms face increased pressure from new goods and technology-induced cost reductions achieved by competing firms in foreign countries.

Most technology diffusion occurs because there are private incentives to adopt new technologies: they are either cost-reducing or provide new products that are attractive to consumers. New green technologies are usually different. Often they are more costly than existing technology. And newer environmentally-friendly products are not always more desirable to consumers than existing products. Hence private incentives to adopt environmentally friendly technologies will be inadequate in the absence of environmental policy. Diffusion may occur in the absence of such policy when technology is embodied in imported capital equipment. But, overall, technology diffusion and environmental policy are complements, not substitutes. New technology cannot solve environmental problems unless there is an incentive to adopt it.

Gallagher (2006) provides a useful example of this point in her study of technology transfer to China in the auto sector. She found that foreign automakers did not transfer their most effective emission control technologies to China and that the explanation is that there was little incentive to do so: local environmental regulations did not set emission standards at a level that created a demand for the more effective technology. On the other hand, the fuel efficiency of technologies transferred to China was similar to that used in cars in the US. There are market incentives to sell fuel-efficient cars (consumers benefit from lower costs per kilometer driven) but incentives to sell low-emission vehicles do not exist unless emission externalities are internalized.

Trade is important not only as a mechanism to increase the rate of technology diffusion; it can also play a role in facilitating the implementation of more stringent environmental policy (which is necessary to create incentives for diffusion). Lovely and Popp (2011) find that increased openness to trade makes it more likely that countries will adopt more

stringent environmental regulations because it increases access to cost-reducing abatement technologies. Using a political economy framework, they study the implementation of NO_X and SO_2 regulations in coal-fired power plants and found that trade had conflicting effects on the adoption of new regulations. On the one hand, openness to trade increases concerns about international competitiveness, which acts as a damper on efforts to tighten regulations, but on the other hand, it lowers abatement costs via access to pollution control technologies. They find that the second effect dominates empirically, and that this can help explain why developing countries adopted regulations at lower levels of per capital income than did their predecessors.

The possibility that technology adoption issues might allow developing countries to leapfrog past developed countries and move quickly to a greener growth has received considerable attention in policy discussions.[13] There is much evidence that many technologies have "lock-in" effects – for example, workers (and consumers) develop skills that are specific to current technologies and there may be complementarities and network effects that make it costly for new technologies to displace old one. Economic history tells us that past major technology transitions (such as from wood to coal to oil as an energy source, or from sail to steam in shipping) did not occur quickly even when the new technology was superior. Transitions in the past have taken decades. This raises the possibility that a newly industrializing country might have an advantage in that it may not already be "locked in" to the old technology and could jump right to a new, more environmentally friendly technology.

Brevis, Krugman and Tsiddon (1993) develop a simple model that exhibits the possibility of leap-frogging. In their model, there is learning specific to a manufacturing technology, and it is assumed that the learning does not spill over borders. If initially one country (call it the Leader) has a comparative advantage in manufacturing, then over time its productivity improves via the learning effect. Now suppose that a new technology

[13] See Sauter and Watson (2008) for a review and some case studies.

appears that is more productive than the old technology (assuming the same amount of time has been spent learning in each case). Then the Leader may not adopt it because its experience with the old technology means that the old technology is still more attractive to it. But a newly industrializing country (the Follower) will adopt the new technology because it has no experience with either and so the new technology is more attractive. Over time as the Follower learns, it eventually eclipses the Leader and dominates the industry. This model is of course highly stylized, and the result is in part driven by the implicit assumption that the Follower has the skilled workers, infrastructure and intermediate goods and service producers that are necessary to support the new technology.

If this is an accurate representation of reality, then it raises the possibility that a developing country might, for example, eschew fossil fuel-based technologies and move directly to an economy based on green energy. The evidence for leapfrogging of this magnitude, however, is weak. There is evidence such as that from Lovely and Popp (2011) noted above that the transition from dirty to clean technologies can be faster for developing countries than for developed countries. As another example, Hilton (2001) found that the phasing out of lead in gasoline happened faster in the countries that began the process after other countries had already done so (he compared countries that began the process before and after 1979). However, there is little evidence of the more dramatic form of leapfrogging at a national level in which a developing country leaps ahead of incumbents by adopting a more advanced technology that the incumbents had chosen to avoid. Cell phones are a popular example, as many communities in developing countries have skipped the landline telephone technology and gone right to cell phones. However, this process built on a base of experience with cell phone adoption in developed countries.

Comin and Hobijn (2004) in their study of the diffusion of 20 technologies across 23 countries over the period 1788-2001 found that most new technologies were adopted first

in high-income countries and trickled down to other countries over time. There is a high correlation between the leaders in the adoption of new technologies and leaders in the adoption of old technologies. That is, they do not find support for the leapfrogging hypothesis. They do find evidence of lock-in: there is evidence of significant adoption costs that lead to long lags in the adoption of new technologies and continued use of older technologies. However, they hypothesize that the learning and or networks that lead to these lock-in effects are at least partially transferrable across technologies, which reduces the likelihood of leapfrogging. In short, the adoption of new technologies is costly, but the evidence suggests that the adoption costs have been relatively lower for those countries with previous experience with the older frontier technologies. Comin and Hobijn do, however, find that diffusion rates across countries have speeded up considerably since the World War II. This is consistent with the hypothesis that via increased openness to trade and investment newly industrializing countries should (if the right incentives are in place) be in a position to adopt state-of-the-art abatement technologies at much lower income levels than in the past.

The existence of technology lock-in has some important implications for the design of environmental policy. Acemoglu et al. (2009) develop a model of technological change in which the direction of innovation is path dependent. There are two technologies that are substitutes: one is green and the other (which is initially dominant) is emission-intensive. Innovators focus their efforts on improving productivity where the potential return is highest and because the market size for the dirty technology is large, they focus their efforts there. Their success in innovating increases the size of the dirty technology sector, which reinforces the incentives to innovate there, leading to a lock-in effect. Their model thus has two externalities - there is a pollution externality, but there is also a market size externality that affects the allocation of innovation effort. This is an economy that has two potential growth paths: one is green and the other is dirty and is not sustainable. Efficient environmental policy requires an intervention that moves the economy onto the green growth path; and this requires a package of policies – emission

taxes or targets are needed to internalize the pollution externality and R&D subsidies are needed to direct technical change towards green innovation.

For our purposes, an important issue is how international trade would affect the structure of optimal policies. In other contexts where there are learning and agglomeration spillovers in the innovation process, trade restrictions can (in theory) be welfare-improving for the tariff-imposing country (assuming that there is no retaliation). Melitz (2005) reconsiders the infant industry argument for protection and shows how tariffs and quotas can be welfare-enhancing in the presence of learning spillovers across firms within a sector. In his model, learning spillovers result in positive production externalities. Trade restrictions that promote local production can therefore lead to increased productivity. Redding (1999) builds on endogenous growth models with innovation spillovers such as Grossman and Helpman (1991) and shows how trade policy can alter comparative advantage and move a country onto a higher growth path. Although a country may have initially have a comparative advantage in the "low-tech sector", long run growth can be higher if the economy moves into sectors where the potential for increased productivity growth is higher (the "high-tech sector"). If innovation spillovers lead to positive production externalities in the high-tech sector, then trade policies that promote that sector can be beneficial. Empirical evidence on the effectiveness of such strategies is sparse, but in a recent paper, Nunn and Trefler (2010) find evidence that there is a positive correlation between the skill-bias of tariffs and long-run growth, and attribute some (but not all) of this to the benefits of promoting innovation-intensive sectors.

The implications of trade policy in the context of learning spillovers in the green technology sector have not yet been studied in depth, although the issue is touched upon briefly in the working paper version of Acemoglu et al. (1999). Hence at this point any conclusions are speculative. Since the key market failure is driven by spillovers in the innovation sector, trade restrictions are second-best instruments – as is standard in the

distortions and targeting literature,[14] the benefits of trade restrictions are reduced or eliminated if efficient levels of subsidies for the innovation sector are available. In addition, trade restrictions can be counterproductive if the learning spillovers are international in scope; that is, if technology transfer and spillovers across countries helps to improve local productivity. Finally, the green technology sector differs somewhat from the industrial sectors examined in the usual infant industry argument: green technology is often an input into the production of final goods and in cases where it yields a final consumption good, that good is typically a close substitute for an existing (pollution-intensive) version of the good. Governments have to be concerned that if protecting the green technology sector drives up prices, this will discourage use of the green technology. Hence a delicate balancing of environmental policies (to create demand for the green technology), R&D subsidies (to stimulate innovation), and possible trade protection (to protect the nascent green sector) would be required.

For a relatively small, newly industrializing country using trade instruments to protect the green technology sector would seem to be counterproductive. Such a country would stand to gain from importing green technology and R&D is likely to be focused on modifying or enhancing technologies to fit local needs. Trade restrictions would simply raise costs. If there are lock-in effects such as in Acemoglu et al. (2009), it means that the world as a whole is likely on a growth path that is dirtier than would be efficient, but there is little a small country can do about this other than ensuring that incentives are in place to encourage the diffusion of whatever green technology is available.[15]

[14] For a good exposition, see Dixit (1985).

[15] Sinclair-Desgagne (2008) and Steenblik and Geloso Grosso (2011) document the importance (and recent growth) of the environmental services industry. That is, efficient pollution abatement (or green production and consumption) requires access to a large market with specialized producers of goods and services who act as intermediate inputs into the abatement process. This market is international in scope. Trade restrictions that restrict market access would increase the size of the local environmental services sector, but would also increase costs for users of these services. For a small country, the latter effect would be expected to dominate.

For a larger innovating country that is considering trying to move to a different growth path, the problem is more complex. One concern is the competitiveness or pollution haven issue: stringent environmental policies aimed at trying to shift the economy towards green goods could shift production of dirty goods elsewhere and reduce the incentives for innovation.[16] This could be alleviated by international coordination of environmental policies; but failure to achieve such an agreement would create incentives for some countries to consider the use of border taxes to restrict imports of dirty goods. I discuss border taxes in the next section of the paper.

Finally, the literature on agglomeration and endogenous comparative advantage raises the possibility that if a major shift to green technology is projected to happen in the future, then there may be first mover advantages for a country that creates incentives to attract and nurture that industry. That is, an industrial policy targeting green technology could potentially yield long term benefits for a country with a market sufficiently large if it is projected that there will be a significantly strong for the demand for the technology from the rest of the world in the future.

[16] This issue is discussed in Acemoglu et al. (2009).

5. Natural capital

While economic growth and environmental quality are often discussed as if they are substitutes, this is not the case when the quality and sustainability of natural capital is essential to human health or as an input into production. The role of natural capital in contributing to economic well-being is most evident in the case of renewable resource-based industries such as fisheries, forestry, and agriculture. Environmental and conservation problems arise from two types of externalities. Some externalities are internal to the affected industry. For example, if multiple agents have access to a stock of fish, then when one fisher increases his or her harvest, this imposes costs on other fishers by reducing the stock. These types of externalities give rise to problems of resource management and conservation. Other types of externalities are cross-sectoral. For example, industrial pollution can kill fish stocks and acid rain caused by sulfur dioxide emissions can damage forests and fresh-water lakes. In these cases there are tradeoffs across sectors. More stringent environmental regulation can reduce productivity in the industrial sector but raise productivity in sectors more dependent on natural capital.

International trade can have important and sometimes irreversible effects on the sustainability of natural capital in renewable resource industries. The effects can differ depending on the type of externality, so I will discuss each in turn, starting with the case where externalities are internal to an industry (such as forestry and fishing).

Openness to international trade represents both a threat and an opportunity for those in the renewable resource sector. It is an opportunity because of the potential benefits of access to large export markets. It is a threat because, if externalities are not internalized, the pressures on resource stock from an export-induced expansion can lead to the collapse of the resource stock. Chichilnisky (1994) and Brander and Taylor (1997) develop simple models of an economy with an open-access renewable resource sector; and they consider the effects of trade liberalization when harvest externalities are not internalized. If the

country ends up exporting goods from the renewable resource sector, then there can be short run gains from trade but long run losses from trade. The economy increases its consumption in the short run, but this is at the expense of depleting its environmental capital.

The effects of trade on the renewable resource sector depend on the management regime. In an efficient regime, managers trade off the costs of investing in sustaining the stock against the benefits of current harvesting. It is sometimes efficient to deplete the stock – for example clearcutting a forest to make way for a city or manufacturing plant can yield net benefits. In other cases it is efficient to preserve the stock to take advantage of the long run flow of income that can be generated from the resource sector. If externalities are internalized, there are gains from trade in this case. However, if externalities are not internalized, then trade can lead to excessive depletion.[17]

There are a variety of institutional arrangements that have evolved over time in response to the externalities in the renewable resource sector. One of the challenges faced by countries with a change in the trade regime is how these institutions respond to the changes in incentives that arise from openness to trade and increased rates of economic growth. In some cases, trade increases the value of the resource stock and so increases the incentives to develop institutions to conserve the resource. In other cases, however, the traditional institutions that have been successful in maintaining the stock in the past may not be sufficient to protect the resource in the face of market-induced pressures driven by the change in the trade regime. Copeland and Taylor (2009) develop a model with imperfect monitoring of resource harvesters. The model predicts that resources that are slow growing, where monitoring is difficult, and where harvest technology is

[17] Brander and Taylor (1997) also show how trade can in some cases help to preserve a resource stock. This could happen when the resource stock has already been depleted prior to trade liberalization. Because of the resource depletion, the economy could have a comparative disadvantage in the resource sector and the opportunity to import could take pressure off local resources.

significantly enhanced via technology transfer are more likely to collapse in response to openness to trade. However, if monitoring is effective then the resource sector can realize significant gains from trade.

There is relatively little systematic empirical work on the effects of trade on the renewable resource sector. There are a number of cases studies that suggest that there has been significant heterogeneity across resource stocks both within and across countries. Copeland and Taylor (2009) cite the example of two different shell fisheries off the west coast of Canada, both of which experienced an export boom in the 1970s. One fishery (abalone) collapsed while the other (geoduck) proved to be sustainable. They hypothesize that differences in monitoring costs were a factor in explaining the different outcomes. Fisheries in countries such as New Zealand have been sustainable in the face of both openness to trade and technical progress in the harvest technology; a result that is due in part to effective monitoring and enforcement of compliance with a quota regime. In contrast, Vetemaa et al. (2006) attributes the depletion of fish stocks off Estonia in the 1990s to a combination of pressure from the opening up of export markets and poor monitoring and enforcement of harvesting restrictions. Similarly, Anferova et al. (2005) describe the role of illegal fishing in contributing to the failure of a harvest quota system off the Russian east coast during 2001-03. In one of the few cross-country studies, Ferreira (2004) found that openness to trade led to significant deforestation only in those countries with weak enforcement of property rights.

If externalities are cross-sectoral – that is, if pollution or environmental damage from one sector kills natural capital in the other sector – the regulatory problem is more complex because tradeoffs have to be made across sectors. One of the key insights from the literature relevant to the issue of green growth is that there are lock-in effects that can be exacerbated by international trade.[18] Imagine that an economy has two sectors, one green (which depends on a healthy stock of natural capital) and the other dirty. There are two

[18] See Copeland and Taylor (1997; 1999).

potential growth paths, one where the green sector is sustainable and thriving and the other where the dirty sector dominates. Suppose that externalities are not internalized at the time trade opens. Then if the country has a comparative advantage in the dirty sector, that sector will expand. Increased pollution will deplete natural capital, which will raise costs in the green sector and this will magnify the comparative advantage of the dirty sector. This positive feedback effect will then cause further expansion of the dirty sector, more pollution and further decline in the green sector. Trade can therefore cause the economy to become locked in to the dirty growth path. A delay in implementing effective environmental policy can make it very difficult to move to the greener growth path.

6. Global environmental problems

Many environmental problems are global in scope. Examples include climate change, biodiversity, and international fisheries depletion. The interaction between trade and global environmental problems adds a layer of complexity that is not present for environmental problems that are purely domestic in scope. For domestic environmental issues, the principal trade-related concerns revolve around the effects of environmental regulation on international competiveness and the role of trade in facilitating access to cost-effective green technology. The same concerns arise when environmental problems are global, but because environmental quality is a global public good, issues of how the pattern of pollution abatement or conservation should be spread across countries, who should pay, and how international agreements should be structured and enforced frame much of the debate.[19] For our purposes here, the issue is how these issues interact with trade.

[19] A large literature exists on International Environmental Agreements. See Barrett (2005) for a review.

6.1. Linkages between trade and international environmental agreements

One of the key issues in dealing with international environmental problems is the extent to which strategies to improve environmental quality will end up being linked to international trade. The Montreal Protocol on ozone-depleting gases contains provisions that restrict trade in products using certain chemicals. In practice, compliance was high and trade instruments were not used. International agreements on biodiversity and endangered species also contain provisions that constrain trade. The Basel Convention on transboundary movement of hazardous waste explicitly restricts trade in toxic substances between OECD and developing countries.

Linkage between international environmental agreements and trade is driven by two major factors. First is the issue of enforcement. In the context of climate change, for example, most of the benefits of policies aimed at reducing greenhouse gases will not accrue to the country implementing the policies – this is the nature of global public goods problems. Consequently an effective treaty will need an enforcement mechanism. The Kyoto Protocol's approach to dealing with climate change by negotiating international emission targets has not been successful and a reading of the literature on international environmental agreements suggests that it is unlikely that any agreement that does not involve some link to trade policy instruments would be enforceable. Second is the issue of leakage. If one country reduces emissions and some of its polluters respond by moving to another jurisdiction then the environmental benefits of emission reduction will be compromised. This leads to calls for trade restrictions that target imports from countries that do not have sufficiently stringent environmental policies.

A number of papers have considered the efficiency implications of linking trade and environmental agreements. Ederington (2002) and Limao (2005) find no advantage to such linkage if pollution is purely local. However, with global pollution both Ederington (2004) and Limao (2005) find that there are efficiency advantages to linking agreements.

Advantages come from both increased potential for enforcement as a wider range of incentives and punishments are available, and from the opportunity to make tradeoffs across the two issues when negotiating. In practice, there has been a great reluctance in the trade policy community to accept the notion of formal linkage between environmental policy agreements and trade agreements. Limao's work also illustrates one reason why those in the trade policy community might be reluctant to go down this route; he shows that one consequence of linkage is that it may result in less enforcement leverage for the trade component of the agreement. That is, although global efficiency is increased, trade may be less free than it would be without linkage.

6.2. Leakage

If an environmental agreement constrains only a subset of countries or polluters, then via the mechanism of the pollution haven hypothesis (discussed above), there will be incentives for pollution intensive industry to expand production in unconstrained countries. This is known as "leakage" in the climate change literature. When pollution is local, pollution haven effects mainly raise concerns about international competitiveness. But when pollution is global, the competitiveness issue is accompanied by concerns that policies will be ineffective in meeting their targets. Reductions in carbon emissions in one country may be offset by increases in carbon-intensive production in other countries. Hence the countries imposing emission reductions will bear the abatement costs but the benefits of emission reductions will be mitigated.

The expected magnitude of carbon leakage is uncertain and currently the subject of a growing literature. There is little solid empirical evidence because relatively few countries have implemented strong policies aimed at reducing carbon emissions. Those countries that have such policies have implemented them fairly recently so there are not a lot of data available to estimate carbon-leakage effects. The pollution haven literature has attempted to estimate leakage effects for other pollutants but, as discussed above, the

literature has had mixed results. The consensus, if there is one, is that leakage exists but for local pollutants such as SO2 and particulate matter it is probably small. However, these results may not be a useful guide to carbon leakage. Because of the importance of energy in the production process and the aggressive policies for carbon reduction needed to tackle climate change, abatement costs may be higher for a wider range of industry than has been the experience for other pollutants. Most estimates of carbon leakage across countries come from CGE models and these typically range from 5% to 20% (see for example Elliott et al. 2010).

From the perspective of newly industrializing countries that choose not to be constrained by an international agreement on climate change, leakage raises a number of concerns. First, the specter of carbon leakage is a powerful rallying point for those opposed to joining an agreement aimed at reducing carbon emissions. That is, without a set of policies aimed at mitigating the potential for carbon leakage, it is unlikely that many high-income countries will commit to a serious program aimed at reducing their own carbon emissions. Since estimates suggest that the expected costs of climate change will fall heavily on low-income countries, this is a cause for concern for developing countries.

Second, carbon leakage or pollution haven effects can make it more difficult for a country that wants to move to a greener growth path because of its effect on comparative advantage. One channel for leakage is via the effects on fossil fuel prices. A reduction in carbon emissions by a coalition of countries would lead to a fall in demand for fossil fuels, thus reducing their price. This would increase the relative cost differential between green and dirty technologies for countries outside the coalition, and thus make a green growth strategy less attractive. Another channel of leakage is via firm relocation: if pollution-intensive industry relocates from coalition to non-coalition countries, it could squeeze out cleaner industry via competition in input markets. The net effect of leakage may well be to increase growth rates in countries outside the coalition in the short run. Whether or not this would lead to long run benefits is difficult to determine. If lock-in

effects such as in Acemoglu et al. (2009) are important and if a shift to a green growth path in the future is inevitable, then leakage effects that increase the likelihood of locking in a carbon-intensive growth path are less attractive.

Finally, carbon leakage is likely to lead to significant trade frictions. Given the political realities, as well as concerns about the efficacy of carbon-reducing policies in the presence of leakage, it is very likely that some countries that commit to reductions in carbon emissions will enact border tax measures that restrict imports from countries that do not make similar commitments.

6.3. Border taxes

In the context of the climate change literature, border taxes are taxes on imports that are applied by a country with a carbon tax (or emission quota) to goods from countries that do not introduce such a policy. The theoretical basis for such a policy derives from Markusen (1975) who considered optimal unilateral policies for a country confronted with global pollution. The first best policy is an agreement under which each country introduces an emission tax to internalize the global externality. In the absence of such an agreement, the optimal second best policy for the Home country is to supplement its own pollution tax with an import tariff targeting pollution-intensive exports from the Foreign country. The motivation for this is that Home has an incentive to use a policy that reduces output in the pollution-intensive industry in the rest of the world. A tariff reduces Home demand for the import good and hence pushes down its world price, thus reducing foreign production and pollution. Copeland (1996) extends Markusen's analysis by showing that a pollution content tariff – a tariff based on the pollution content of the foreign good – would be a superior instrument. Gros (2009) shows that a border tax can raise global welfare because pollution affects both home and foreign utility and the border tax is a second best instrument to target foreign pollution. Recently, Keen and Kotsogiannis (2011) have shown that the use of border taxes is also constrained Pareto

efficient. In the context of our two-country example here, they suppose that Home is able to implement a carbon tax, while Foreign is not. They then consider a policy that maximizes the welfare of Foreign for a given level of welfare in the Home country. If lump sum transfers are available to deal with the international distribution of income[20], then the constrained Pareto efficient policy is for Home to implement both a carbon tax and an import tariff. The logic is similar to that of the Markusen analysis (although Markusen only considered Home's welfare and placed zero weight on Foreign welfare). Regardless of the weight that Foreign places on global pollution, an efficient outcome calls for an agreement under which Foreign introduces a carbon tax because pollution affects Home utility. In the absence of such a tax, Home's tariff is a second best instrument to target foreign pollution.

Such a policy has some disadvantages.[21] It is a blunt instrument: the efficient policy is to target foreign pollution directly and indirect targeting of pollution via trade instruments may not be very effective in reducing foreign emissions. The outcome will depend on foreign supply elasticities and on the available opportunities for the foreign country to redirect its exports to other countries that do not impose such a tariff. Another disadvantage is that because the policy protects local production (and in the example above improves Home's terms of trade) then Home has an incentive to impose such a tariff even if it is not concerned about foreign emissions or even if it expects the effects on foreign emissions will be minimal. The distinction between policies aimed at combatting climate change and those that are merely protectionist can become murky. A third disadvantage is that it may trigger a trade war if the foreign country decides to retaliate.

[20] If lump sum transfers are not available, the result continues to hold; but in this case tariffs are used both to target Foreign pollution and to affect the international distribution of income.

[21] Aside from the economic issues discussed here, there is some debate as to whether such policies would be legal under the WTO. See Fischer and Fox (2009) for a discussion and reference to the relevant literature.

In part because of concerns about the trade policy repercussions of border taxes, the recent literature has also considered some alternatives, such as emission intensity targets or output-based allocation of emission permits (see for example Fischer and Fox, 2009). As discussed earlier in this paper, these policies effectively combine a domestic emission tax or target with an (implicit or explicit) output subsidy. From the trade literature we know that an import tariff is equivalent to an output subsidy financed by a consumption tax on the imported good. Hence these alternative policies simulate some of the elements of the tariff by stimulating local output, but lack the consumption tax component of a tariff and so would be expected to have a smaller effect on the world price of the polluting good (and hence a smaller effect on leakage).

Several studies have used computable general equilibrium (CGE) models to assess the effects of border taxes on leakage and on welfare. The studies differ both in the amount of leakage predicted and on the effects of border taxes in reducing any leakage that does occur. Babiker and Rutherford (2005) find that border taxes (a tariff on carbon intensive imports) applied by a coalition of high income countries has very little effect on carbon leakage, but that it shifts some of the costs of carbon emission reductions from coalition countries to non-coalition countries (mainly via terms of trade effects). For example, in their base case, China gains from emission reductions by the coalition, but if emission reductions are combined with border taxes, then it experiences a fall in GDP (in contrast, they find that China would gain from a deal under which it voluntarily restricted exports of carbon-intensive goods to keep them at baseline levels because it would experience a terms of trade improvement). McKibbin and Wilcoxen (2009) find that border taxes would do little to affect global carbon emissions, in part because their model predicts that leakage would be small, but also because the main effect on non-coalition country carbon emissions would be via the fall in the price of fossil fuels, which would lead to an increase in emissions from the non-traded sectors in non-coalition countries. Elliot et al. (2010) find that leakage across countries would be between 15% and 25% and that a

border tax would reduce about half of this. Mattoo et al. (2009b) consider the effects of border taxes on developing countries. Their model predicts that a restriction on carbon emissions in coalition countries has an adverse effect on competiveness in coalition countries, but carbon leakage would be small. Border taxes would have a relatively small effect on global emissions, but a potentially large negative effect on the manufacturing sectors of developing countries. They note that the magnitude of border taxes would depend on whether they were based on the carbon intensity of production in the domestic market or in the developing country. The adverse impacts on developing countries would be much more severe in the latter case.

There is thus not yet a consensus in the empirical literature on the magnitude of carbon leakage. Nevertheless, it is unlikely that a serious commitment to reduce carbon emissions by countries such as the US would be politically viable unless it was accompanied by some mechanism to deal with real or perceived competitiveness issues. Because the boundary between protectionist and environmentally-motivated border taxes is not transparent, it would be preferable for such a regime to be the outcome of a negotiated arrangement with clear rules.

Developing countries have several options. Some countries may be able to secure exemptions based on per capita income thresholds. For those countries facing some form of border tax regime then as Mattoo et al. (2009b) note, the details of border taxes, such as the emission intensity on which they are based, would have important implications for their trade-reducing impacts. There may also be superior alternatives to consider, such as agreeing to prevent leakage by imposing some form of export restrictions to ensure that exports or carbon intensive goods do not rise beyond the level that they would have attained in the absence of the coalition's emission controls. As noted above, Babiker and Rutherford (2005) find that countries such as China would experience welfare increases from voluntary export restraints. Mattoo et al. (2009b) suggest that an agreement to impose an export tax would be preferable to a regime where coalition countries impose

border taxes. Such an agreement has precedent from countervail cases in other contexts. Countervail cases can arise when there exist subsidies in one country that increase exports and adversely affect producers in another country, and so are similar in principle (in not in law) to cases of implicit export subsidies arising from failure to internalize global pollution externalities. In such cases the aggrieved party has the right to impose a countervailing import tax to offset the effects of the subsidy. But other remedies are possible. For example, in a dispute over softwood lumber trade, the United States accused Canada of subsidizing exports to the U.S. While Canada did not concede that there was such a subsidy, it nevertheless agreed for a period of time to impose an export tax to avoid an American import tariff. Kinnucan and Zhang (2004) and others have shown that such a policy was not only superior to an American import tariff but raised Canadian welfare relative to what it would have been in free trade.

7. Conclusion

There are a number of areas that would benefit from further research. Numerous studies have suggested that technological change will be critical to moderating climate change unless there are radical changes in our lifestyle. Theoretical work such as Acemoglu et al. (2009) suggest that significant public commitment to subsidizing R&D would be needed to move the economy to a greener growth path. An important question is how the presence of international trade affects the design of incentives to accomplish such a transformation.

While there has been much work on the pollution haven hypothesis and the effects of environmental policies on competitiveness, very little of this work uses data from developing countries. Data availability has been a key constraint, but where suitable proxy variables for the stringency of environmental policy can be found, the payoff to such work would be high. There is also very little work that exploits environmental policy differentials across countries (either rich or poor). In the absence of such work it is

difficult to know the extent to which the studies of firm location across different jurisdictions in the US have implications for the international relocation of production.

The research on the pollution haven hypothesis is relevant for the issue of carbon leakage but since we have little experience with serious policies aimed at reducing carbon emissions, most current estimates of carbon leakage rely on simulation models. Estimates vary significantly across models. A careful analysis of the key factors in the models that drive these differences would be informative. Much of this work has focused on the effects of leakage and border measures on developed countries. More work that explores the effects of such policies on growth in developing countries would be useful. An exploration of alternative possible negotiated agreements (such as export taxes aimed at neutralizing leakage effects) would also be fruitful.

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