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Abstract

Border Carbon Adjustment (BCAs) may play an important role in lowering the economic costs of greenhouse gas mitigation and in overcoming political-economy constraints on use of carbon taxes or equivalent measures. A carbon tax plus a full BCA (CTBA) could deal with the competitiveness challenges arising from carbon taxes by using the WTO's National Treatment principle to apply equal levies on domestic production and on imports, and by symmetrically rebating the carbon tax on exports in the manner of a VAT export rebate. This approach would shift the base for carbon taxation from output to consumption and intermediate input use and potentially lower the cost of achieving reductions in emissions. It would avoid the massive measurement and compliance problems associated with BCAs based on foreign emission intensities. By contrast, proposals for import-only BCAs would distort prices of importables relative to exportables, create competitiveness concerns in export industries, generate economic waste and likely create highly divisive trade conflicts and deterioration in the terms of trade for developing countries.

Keywords

Border Carbon Adjustment, Carbon tax, Consumption tax, Greenhouse gas, Global warming, VAT, WTO.

1. Introduction[1]

If current European Commission proposals are adopted, the world may be on the verge of introducing a new trade measure of border carbon adjustments (BCAs) on a large scale (European Commission (EC) 2020, 2021). These measures, which combine environmental and trade policies by levying border adjustments based on the estimated social costs of greenhouse gas emissions, could have enormous implications for both economic and environmental outcomes in both developed and developing countries. The tax rates involved would likely dwarf current tariffs.

An extensive literature has examined potential proposals for BCAs to accompany carbon taxes, or equivalents such as emission trading schemes (ETS), in Energy Intensive and Trade Exposed (EITE) industries (see, for example, Böhringer, Balistreri and Rutherford 2012). This literature has generated important insights into the potential impacts of these measures. In particular, it suggests that they frequently can reduce the cost of cutting emissions relative to use of carbon taxes (or emission trading systems) alone.

Interpretations based on this literature tend to suggest that import barrier mechanisms are much more important than export rebate mechanisms although, as noted by Cosbey et al (2019), this is partly because the EITE industries on which attention has focused are import competing in the richer countries for which they have been analyzed most intensively. Given that a system of carbon taxes would likely need to be expanded, and the rates applied to increase over time if sufficient abatement is to be achieved, it seems dangerous to design a system only for a subset of products in the industrial countries. As the coverage of carbon taxes is expanded either geographically or by commodity, they must increasingly include cases in which EITE products are export oriented.

An important question is the motivation for BCAs. Hillman (2013) offers four potential motivations for BCAs: (i) competitiveness concerns following introduction of carbon taxes or equivalent measures (CTs), (ii) allowing time for domestic producers to adjust to introduction of CTs, (iii) to reduce "leakage" where production in the country imposing such a CT is replaced by production from countries not imposing a CT, and (iv) to create incentives for other countries to adopt CTs. The first three of these are applicable in both small and large countries. The fourth can only be achieved by countries or groups of countries that are collectively large. One additional potential motivation emphasized in this paper is the possibility that a carbon tax plus a border carbon adjustment (CTBA) may allow emission reductions at lower economic cost than a CT alone, as well as potentially helping overcome political-economy resistance to CTs.

It is vitally important to spell out the goals of any BCA proposal because these goals dramatically affect the nature of the desired measures. If, for instance, maintaining "competitiveness" is the goal, then the "problem" is the increase in domestic costs associated with a carbon-tax or equivalent measure. In this case, a relevant criterion for deciding on the level of a BCA is the WTO's National Treatment principle—that imported and domestically produced goods should be treated equally with respect to internal taxation. The rate applied to imports and domestic production would provide a basis for rebating the tax on exports in a similar manner to export rebates under a VAT, eliminating competitiveness concerns of exporters and providing equal treatment for exporting firms and competitors not subject to a carbon tax.

By contrast, if the goal is to reduce "leakage", it might seem logical for BCAs to be based on the emission intensity of foreign production processes relative to domestic processes. This may result in tax rates on imported goods that differ substantially from the impact of a carbon tax on the costs of domestic producers. Much discussion of potential BCAs seems to simply assume that reduction of leakage is "the" goal and that BCAs should be set on the basis of emission intensities of production

1 This paper has benefitted enormously from comments by audience members in presentations at the International Conference of Agricultural Economists, IFPRI, the US International Trade Commission, the World Trade Organization and the International Agricultural Trade Research Consortium.

in each supplying country or even supplying producer, despite the formidable information costs and risk for malfeasance involved in estimating and applying such a multitude of rates. Kortum and Weisbach (2017) estimate it would have been necessary to calculate 15,000 different tax rates under one important US legislative proposal, even if only an average of ten countries supplied each good to the United States.

It is clear that no one policy can achieve both the goal of treating domestic and foreign firms equally and that of basing import levies on foreign emission contents. BCAs set based on foreign emissions will either over or under-compensate domestic producers for the increase in their costs associated with the carbon tax. Tax rates based on emission intensities in foreign markets do not provide an obvious basis for setting rebates to reduce or eliminate the impact of a carbon tax on the costs of export-oriented producers.

Most of the focus in this paper is on policies designed to equalize the impact of a domestic carbon tax and a BCA on the costs of domestic and imported goods. This is because these impacts seem to be central to the enormous political difficulties in implementing production-based carbon taxes noted by Nordhaus (2019). Both import-competing and export-oriented firms in traded good industries have serious and understandable concerns about the impacts of carbon taxes on their costs and the inequality of treatment between firms producing subject to carbon taxes and those not subject to such taxes—with the concerns of import-competing firms addressable using import barriers and those of export-oriented firms by export rebates. By contrast, as pointed out by Kortum and Weisbach (2017), reducing “leakage” is not necessarily a policy goal. What would seem to matter more is the cost effectiveness of the measures in reducing global emissions, or the global reduction in emissions for any given emission reduction budget.

While interest groups may talk about “leakage” problems, much of this is a cover for real but self-interested concerns about increased competition. If competitiveness is the political problem and a BCA can deal with this problem in a manner consistent with national treatment, then the chances of progress on decarbonization seem likely to be much higher. Before rejecting the idea of carbon taxes as a political impossibility and moving to truly radical measures like carbon clubs with free trade among an in-group of developed countries and substantial barriers against imports from developing countries (Nordhaus 2019), perhaps more attention should be focused on CTs buttressed by BCAs to deal with competitiveness problems—a combination that turns a production-based carbon tax into a corresponding tax on consumption.

As the major contributions of emissions from agriculture and land use change become more widely recognized (Mamun, Martin and Tokgoz 2020; Laborde et al 2021), it seems likely that greater consideration will be given to the potential use of carbon taxes and, potentially, BCAs. Several analyses of potential use of BCAs in agriculture have already appeared (eg Blandford 2018; Nordin et al 2019) as well as studies that consider potential economy-wide applications of BCAs (eg Mattoo et al 2009; Corong et al 2021). Even if agriculture is not directly affected by a BCA, it would be affected by the planned inclusion of products like nitrogen fertilizers under the proposed EU Carbon Border Adjustment Mechanism (EC 2021, p79).

Many of the lessons distilled from the current literature have been based on results from CGE models. While these models can make an important contribution to understanding, it is vitally important that the key parameters that drive their results are carefully evaluated. Here, the wide variation in the assumptions made about these parameter values is striking. Elliot et al (2012, p466), for instance, assume that emissions are in fixed proportion to output of each energy-intensive commodity. Bellora and Fontagé (2020) and many other studies using the GTAP-E model use an elasticity of substitution of 0.5 between energy and capital, which accommodates some, limited substitution between energy (assumed to be the primary source of GHG emissions) and other inputs. McKibbin et al (2018), by contrast, use elasticities of substitution between energy and other inputs, and between different energy sources, that are strongly differentiated by sector and, in some cases, considerably above 0.5.

Bednar-Friedl et al (2012) show that the GTAP-E database neglects process emissions, other than those associated with fuel use, and that this results in underestimation of the impacts of BCAs. This finding is likely to be particularly important for agricultural emissions, where the vast majority of GHG emissions are associated with processes like methane emissions from ruminants or from flooded rice fields—a category of emissions that attracted particular attention with the Global Methane Pledge at COP26 (IEA 2021). This finding also raises the importance of approaches that invest in developing new technologies that reduce emissions, rather than using incentives to choose between the currently available technologies if the transformative reductions in emissions needed to avoid massive global warming are to be achieved (Gautam et al 2022).

This paper uses simple, transparent techniques to explore the key linkages between emissions and border measures as complements to carbon-taxes or equivalent approaches such as emission trading schemes. It first considers the relationship between carbon-taxes and BCAs in small, open economies. Next, it examines the question of dealing with embodied emissions, those embodied in production inputs rather than from fuel combustion. Then it considers the global impacts of alternative carbon tax and BCA measures, showing why the move from taxing output to taxing demand may make a difference to emissions and to efficiency when only some countries use carbon abatement measures. Finally, it examines the arguments for and against BCAs differentiated by the perceived carbon content of production in the exporting country.

2. Interventions and Emissions in a Small, Open Economy

For any industry, a carbon abatement policy such as a carbon tax or an emissions trading system affects emissions through two channels: (i) changes in technique, and (ii) changes in output. Where all emissions are associated with fuel use, and emission taxes are imposed based on fuel use, the approach of Bellora and Fontagné (2020) can be used to model the changes in technique associated with the emission tax. As the emission tax rises, producers reduce their use of fuel, and the associated emissions, <u>at a constant output level</u>, by:

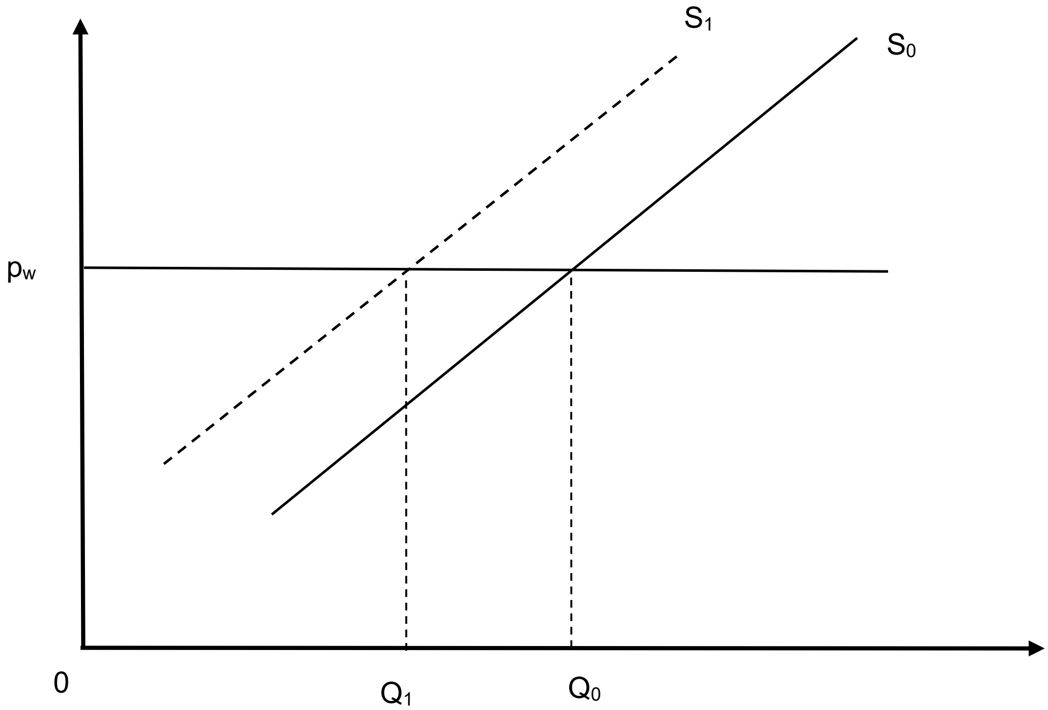
(1) $$\hat{e} = \eta_f \, \tau_f = -(1-s)\sigma . \tau_f$$

where $\hat{e}$ is the proportional change in fuel use and in emissions; η_f is the elasticity of demand for fuel at constant output of the product; τ_f is the proportional change in the power of the tax on fuel use (equal to one plus the proportional tax on fuel); s is the share of fuel in production costs; and σ is the elasticity of substitution between fuel and other inputs.

The formulation of change in technique implicit in equation (1) can be extended to pollution generated from sources other than fuel if the generation of those emissions can be monitored and discouraged using a tax or transferable quota requirement. This might apply to process emissions from cement, where production technologies can readily be monitored. In principle, it might also be used with methane emissions from ruminant digestion or flooded rice fields, but the costs of monitoring whether emissions are actually being reduced would be much higher than with large scale manufacturing processes.

The second way in which carbon taxes can reduce emissions is through their effects on output, which can be reduced by reducing either the supply of, or the demand for, products whose production generates emissions. Beginning with the simplest case of a carbon tax on production in one country, increases in costs from the tax raise the price at which output can be sold, shifting the supply curve upwards. Diagrammatically, the effect of introducing a carbon tax that raises the price of fuel by the proportion τ_f is shown in Figure 1. Competitiveness concerns about the reduction in output resulting from the carbon tax—from Q_0 to Q_1 in Figure 1—and the possibility that the reduction in domestic production may be replaced by imports—is perhaps the main motivation for BCAs.

Figure 1. The effect of a change in a carbon tax on output in a small, open economy



Algebraically, the change in output is given by $-\eta_s s\tau_f$ where the share s converts the change in the fuel price into the change in total costs and the elasticity of supply for the good, η_s converts this change in costs into an output change at constant prices. The total change in emissions is then given by:

(2) $$\hat{e} = -[(1-s)\sigma. + \eta_s s]\tau_f$$

where the first term within the brackets captures the incentive to change technique to reduce fuel use. The second captures the impact of the change in output on emissions. The proportional change in the power of the tax on fuel (τ_f) is multiplied by the share of fuel in total cost to allow it to be compared with a change in the product price. Once this is done, $s.\tau_f$ is multiplied by the elasticity of output supply (η_s) to get the proportional impact on product output. The total impact on emissions is the sum of the change of technique effect from (1) and the output effect.

A major concern that motivates use of BCAs is that the reductions in output associated with a carbon tax may cause domestically produced goods to be replaced by imported goods, perhaps not subject to a carbon tax, and perhaps having higher emission intensities. The problem arises in much the same way for exportable goods. A carbon tax on an exportable will reduce domestic output and lead to part (or all) of its initial sales being replaced by production from other suppliers. As noted by Blandford (2018), the effect of this replacement on global emissions depends on the relative emission intensity (emissions per unit of output) of foreign-produced goods relative to domestic goods. If the domestically produced goods have a lower emission intensity than foreign-produced goods, then replacing them with higher-intensity imports may increase global emissions. Clearly, this does not constitute a general case for replacing imports with domestic production, because some imports may have emission intensities below domestic production. And recognizing the importance of the problem for exportables makes clear that just dealing with effects on imports is only a partial response.

Differences in emissions per unit of output between countries can be substantial, as is evident from the agricultural examples in Table 1. As is evident from the table, there is a tendency for emission intensities of agricultural goods to be higher in poorer countries than in rich, although this is not always the case, as is evident in the case of rice. An implication of this table is that carbon taxes associated with products like beef could be very large. At a carbon price of $50 per ton and a global beef price of $4000 per ton, the tax equivalent at OECD intensities would be around 20 percent, while the tax equivalent would be 40 percent at the average non-OECD intensity.

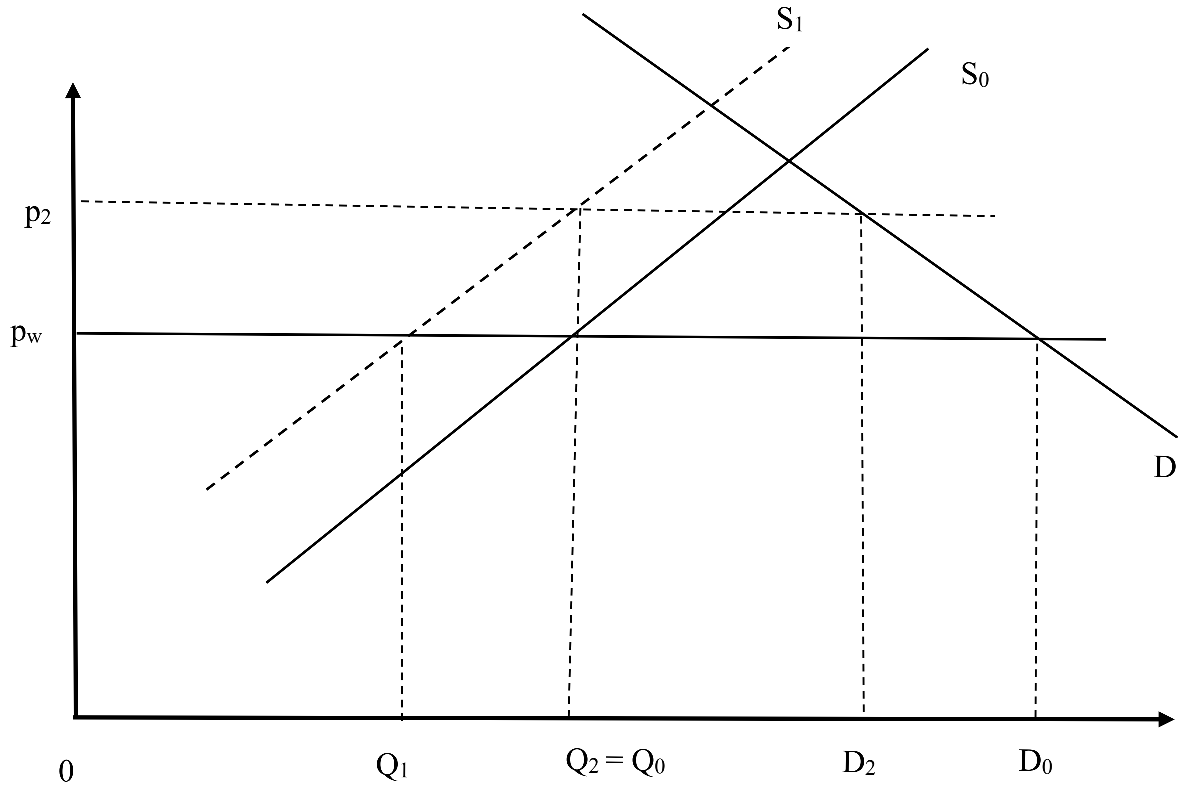
Table 1. Average emission intensity and agricultural emissions (shares in %) by Commodity and Country Grouping, 2015

	OECD		Non-OECD		World	
	Intensity	**Share (%)**	**Intensity**	**Share (%)**	**Intensity**	**Share (%)**
Rice	1.1	3.4	0.9	18.8	0.9	15.5
Other Cereals	0.2	18.7	0.2	7.4	0.2	9.8
Milk	0.5	18.8	1.3	17.8	1.0	18.0
Ruminant meat	16.0	49.2	32.4	50.5	26.6	50.2
Pigmeat	1.7	7.3	1.4	3.2	1.5	4.0
Poultry meat	0.3	1.4	0.7	1.3	0.6	1.3
Eggs	0.5	1.1	0.8	1.1	0.7	1.1
Total (from incl sectors)		100		100		100

Note: 1. Intensity measured in kg of CO_2 equivalent per kg of output.
Source: Mamun, Martin and Tokgoz (2020).

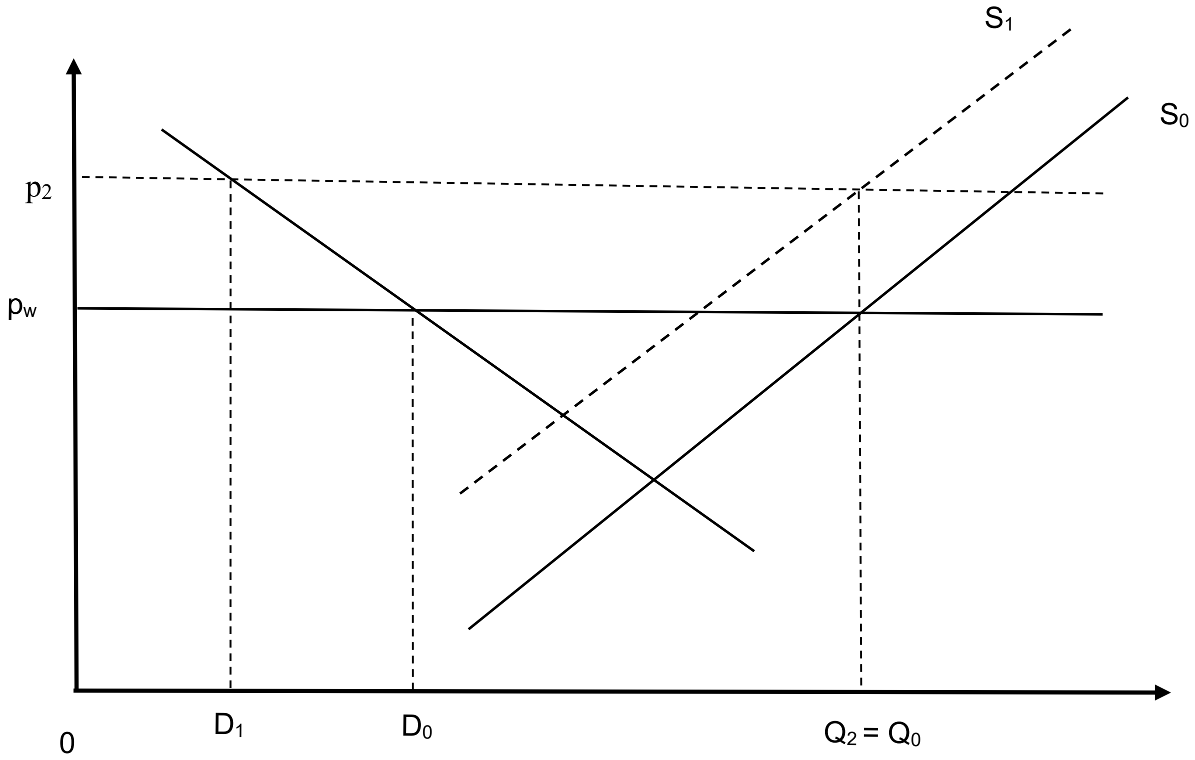
Adding an import BCA at the same rate as the cost increase created by a carbon tax, i.e. at a rate $\tau_g = s\tau_f$ for the finished good, raises the domestic price of the good. This case is shown, for an importable good, in Figure 2 by the shift in the supply curve from S_0 to S_1. A curious feature of a BCA as an environmental measure is that it eliminates the incentive to reduce output created by the carbon tax, and the associated reduction in domestic emissions. With just the carbon tax, output would fall from Q_0 to Q_1. When the BCA is added, output returns to its original level of Q_0. The BCA, however, also creates a tax on consumption, raising the consumer price from p_w to p_2 and reducing demand from D_0 to D_2. This tax on demand is a key means by which a carbon tax plus BCA (CTBA) can contribute to environmental goals, despite its neutralization of the direct incentive for output reduction created by the carbon tax.

Figure 2. Effects of a CTBA on an importable good in a small, open economy



A BCA can also be applied on exports. Following the example of a VAT, this would likely take the form of an export rebate at the common rate of the CTBA. The effects on output and demand are similar to those for an importable. The domestic price of the good is increased from p_w to p_2 because export sales yield p_w plus a rebate of (p_2 - p_w). Producers are compensated for the increase in their costs associated with the carbon tax and so maintain their original level of output. Consumers face the higher price p_2 and so reduce their consumption from its pre-carbon tax level, D_0 to D_1. The competitiveness concerns of producers have been dealt with, while the reduction in consumer demand for the emission-intensive good contributes to global emission reduction.

Figure 3. Effects of a CTBA on an exported good in a small, open economy



The contribution of a full CTBA (ie one with an import levy and an export rebate) to reducing global warming arises not from reductions in domestic production, but from reductions in demand for emission-intensive goods, whether importable or exportable. Because a true BCA operates in conjunction with a carbon tax, there is also an incentive to change production techniques to reduce emissions. The difference between a carbon tax and a carbon tax plus full BCA is that the carbon tax reduces domestic output, while the full CTBA reduces domestic demand while leaving incentives for domestic production unchanged.

Shifting from a BCA designed to deal with competitiveness and equal treatment challenges to one based on stemming “leakage” results in a focus on the emission content of imported goods, rather than on the costs incurred by domestic producers. “Leakage-focused” BCAs do not have the self-cancelling feature of removing the impact on competitiveness of the carbon tax. If imports were sourced from relatively low-emission intensity suppliers like non-OECD rice producers, the compensation to domestic producers from an import BCA would be less than the cost increase. If imports were sourced from high emission-intensity countries, domestic producers would be more than compensated. There would be a tendency for imports to shift from high-intensity suppliers to low intensity suppliers, which would be helpful, although high-emission intensity suppliers would respond by shifting their exports to other markets. It is also very unclear how an export BCA would be determined with a view to minimizing “leakage”.

Emissions from production of nontraded goods raise some additional complexities that need to be considered even though nontraded goods are not directly subject to a BCA. The burden of a carbon tax on these commodities is shared between the producer and the purchaser. Thus, in contrast with the case of tradable goods, the price of the good does not rise in line with the carbon tax, but only partially, with the precise extent of the price rise determined by a combination of the demand and supply elasticities for the good.

While very clear and simple, the effects of the CTBA shown in Figures 2 and 3 are slightly incomplete. Import demand is diminished by the reduction in consumer demand, while export supply is augmented for the same reason. Restoring the initial balance between income and expenditure will likely require both changes in spending and changes in the prices of nontraded goods, that is changes in the real exchange rate. Capturing these effects requires a general equilibrium model, but does not change the key insights obtained from the diagrams—and particularly the shift from tax on output to taxes on demand associated with introduction of a full CTBA.

The general equilibrium effects of introducing a CTBA involve rises in prices of nontraded goods, partly in response to the direct impact of a carbon tax. The increases in the consumer prices of traded goods associated with a CTBA will shift demand towards nontraded goods, placing further upward pressure on their price. Any increase in spending associated with redistribution of government revenues from the carbon tax and the BCA will further increase demand for nontraded goods and put additional upward pressure on their prices. The end result is likely to involve an increase in the price of nontraded goods (or equivalently) a real exchange rate appreciation, that will draw resources into production of nontraded goods and away from production of traded goods, allowing restoration of the initial trade balance.

A CTBA on an imported good generates two sources of government revenue—one from the carbon tax and one from the BCA on imports. Except when import penetration is very high, the revenue from the carbon tax would be greater than that from the BCA on imports. The export rebate requires governments to pay out some of their revenue from the carbon tax and the import BCA. With balanced trade, there would be no net revenue from a full BCA. Governments would, however, still receive revenues from the carbon tax.

3. Embodied Emissions

A key question is whether a BCA should be based only on the direct emissions from production of a good or should account for indirect emissions from the production of intermediate inputs used in its production. Initially, it might seem obvious that both direct impacts and those embedded in intermediate inputs should be included, as in EC (2021). But this is not necessarily consistent with equal treatment of domestic and imported goods. Where, for instance, some inputs are subject to a carbon tax but not a BCA—as with exportable inputs under an import-only BCA regime—the CT has no effect on the price of the input in a small, open economy. While the intermediate input producer suffers a loss of competitiveness, her price is determined on world markets and she is unable to pass the additional cost on to the producer of the final good. In this situation, proposals like that in EC (2021, Annex III, p4) to calculate the BCA rate for each product by adding the emissions from its production with those from production of its inputs, whether or not the producers of traded good actually bear the burden of those costs, would over-compensate producers by setting BCAs on imports above the costs imposed on domestic firms.

Embedded emissions are typically categorized into three groups: Scope 1 emissions, that result directly from activities undertaken by a firm (such as burning fuel); Scope 2 emissions resulting from production of the electricity or other energy used by the firm; and Scope 3 emissions, such as those resulting from production of intermediate inputs used by the firm (GHG Protocol 2004). It is clear that indirect emissions under Scope 2 and Scope 3 are part of the carbon footprint for a final good and some proposals envisage their inclusion in the calculation of a BCA (eg EC 2021, p72).

Whenever an import or export BCA is imposed on goods that are used by another firm as inputs, the costs of the downstream firm will increase. In this situation, the BCA for the downstream good should take these costs into account, as well as the costs associated with the carbon tax on its own (Scope 1) emissions. These adjustments should be made for intermediate products that are covered by both a carbon tax a BCA, but not for intermediate inputs covered only by a CT, or not subject to a CT at all.

4. Policy Choices for an Individual Economy

Policymakers in an individual country seeking to make a contribution to reducing global warming can choose between a carbon tax: (i) without a BCA, (ii) with an import only BCA and (iii) with a full BCA. The key problem of a carbon tax without a BCA is likely to be political. Producers in trade-exposed sectors are likely to resist imposition of a carbon tax without a BCA because of concerns about their competitiveness.

An import only BCA is frequently recommended (eg EC 2021). This approach clearly reduces concerns about competitiveness among import-oriented producers. Some also advocate this approach because an export rebate system is seen as "subsidizing" exports of emission-intensive goods (eg Blandford 2018, p16). There are several concerns with these arguments. Firstly, an export BCA would only be applied on industries where a carbon tax has been levied to reduce emissions so there is no subsidy to emission-intensive goods, only relief from the burden of the carbon tax. Secondly, failing to have an export rebate for a commodity can be seen as failing to contribute to reducing demand for this product by raising its price to domestic users. Thirdly, providing BCAs only for importable commodities is a potentially very costly policy because of the economic distortions it creates.

Import only BCAs raise the cost of producing exports both through input-output linkages and through increases in the prices of nontraded goods, shrinking exports just as traditional protectionist policies did and reducing the range of products that can profitably be exported (Dornbusch, Fischer and Samuelson 1977). Both production and consumption decisions are distorted by the fact that some commodities (importables) receive support from BCAs while exportables do not. The evidence is that import only BCAs would be an inefficient approach to reducing emissions (Mattoo et al 2009). If imposed primarily by developed countries, such import-only BCAs have been shown to have very adverse implications for the export prospects of developing countries (Mattoo et al 2012). This is because the full BCA with export rebates eliminates the distortion towards import competing goods and the damage to the export prospects for developing countries in the countries using a carbon tax with a full BCA (CTBA). Just like a VAT (Grossman 1980), a full CTBA would be trade neutral, while an import-only BCA is trade distorting.

If import only CTBAs were introduced in many countries double taxation could be a serious problem. Exports would be double taxed by being subjected to a carbon tax in production and a BCA on entry into the partner market. One way to overcome this would for BCAs to be reduced on products that have been produced subject to a carbon tax, or perhaps using low emission technologies. But this approach will overcome the problem of double taxation on my exports only if all my trading partners agree to implement their CTBAs in this way. In the absence of such an agreement, the potential for trade conflict seems very serious. A much simpler way for each country to avoid its exports being subject to double taxation is to implement its own export rebate system.

While import only BCAs can be rejected on economic grounds, there is an important question about the relevant economic merits of a production tax approach in the form of a carbon tax alone, and a tax on demand imposed through a CTBA. One simple economic criterion for deciding between the two alternatives is their relative economic costs. If the carbon tax can be levied only on part of world demand or part of world supply, it seems likely that the economic losses due to its imposition would be lower if it is imposed on the less elastic side of the market—an intuition that is examined in the next section.

There are good reasons to expect that elasticities of demand for individual goods will be smaller than elasticities of supply. Except for products linked to very specific natural resources, supply elasticities for individual commodities are typically quite high in the long term relevant to this policy question. In the CGE models that have been so heavily used to assess the implications of BCAs, the partial equilibrium elasticities for manufactured goods are typically infinite, with only general equilibrium changes in the prices of inputs giving them an upward slope. While the supply elasticities for agricultural goods are constrained by aggregate land, the elasticity of supply for individual commodities is higher because of the ability to move land between agricultural activities. Demand for individual goods, by contrast, tends to be relatively inelastic—consumer demands because of consumer preferences, and intermediate demands because of relatively limited flexibility in substituting between inputs. In the CGE models used to evaluate BCAs, these features are strongly present, with low or zero elasticities of substitution between inputs, and relatively low elasticities of consumer demand. Elasticities of demand for agricultural goods tend to be particularly low.

When we consider a BCA affecting a range of products in a country, what matters is not just individual price responses but the full set of own and cross price effects of demand and supply. The CGE models used to evaluate BCA proposals embody a representation of these—the convexity of the profit function in prices and the concavity of final expenditure and intermediate input demand functions. For the reasons discussed for single elasticities, there is every reason to suppose that demand responses are smaller than supply responses. This means that the welfare costs of a system of BCA measures that tax demand are likely to be lower than for a corresponding set of carbon taxes—without supporting BCA measures—that tax production.

In terms of political economy, there are also important questions about import only BCAs. Exporters are worse off under import-only BCAs than under a carbon tax alone. Not only do they have to pay carbon taxes on their own emissions, but they also face higher prices for any of their inputs produced by import-competing firms. Opposition from organized exporter interests may well result in neither a carbon tax nor a BCA being implemented. There are also likely to be serious North-South political conflicts since import only BCAs adopted by rich countries have been shown to create very serious adverse terms of trade impacts for developing countries (Böhringer, Carbone and Rutherford 2016; Mattoo et al 2012). These authors found that moving to a full BCA removed these terms of trade effects.

Many authors recognize the desirability of a full BCA with export rebates but conclude that export rebates are not possible under WTO rules. Trachtman (2017 p491) indicates that this is far from clear, particularly given Footnote 1 to the Agreement on Subsidies and Countervailing measures “the exemption of an exported product from duties or taxes borne by the like product ….not in excess of those which have accrued, shall not be deemed a subsidy”. Given the analogy between a rebate of such a carbon tax and the rebates used with Value Added Taxes, it seems plausible that a rebate could be designed to be consistent with WTO rules.

Some, such as Heine (2020), OECD (2020) and Neuhoff et al (2015) argue for an excise or sales tax approach that could tax demand without the need for export rebates. This seems a very complex approach to avoiding potential WTO compliance issues. A fundamental difference between sales/excise taxes and carbon taxes is that excise taxes are levied only on final consumption, while carbon taxes would apply to intermediate use as well as final consumption. This means that the collection systems—focused on final retail sales—developed for sales/excise taxes would be massively incomplete for potential demand-based carbon taxes. Extension of such transaction-based taxes to include intermediate consumption could easily degenerate into cascading taxes where the amount collected depended on how many firms were involved in the value chain, unless detailed records unlike anything used for sales/excise taxes were kept of how much had been paid at earlier stages.

Neuhoff et al (2015) propose an entirely new collection system where tax liabilities would be incurred but not paid when goods are produced or imported and exempted when the good was exported. While reminiscent of duty suspension schemes, it would raise an enormous range of questions. How long would be allowed between incurring the liability and payment? Which producing or importing firm’s liability for future payment would be exempted when a different trading firm exported 500 tons of beef? In any event, such a system involves a de facto export rebate. An exporter gets something just as valuable as a cash rebate, the waiving of a tax liability. Would it really be worth creating such a complicated and entirely new system just to avoid the term “export rebate”? If WTO members and WTO Dispute Settlement panels were concerned about explicit export rebates surely they would be just as concerned about disguised export rebates of this type.

This type of problem has been addressed in typical destination-based VAT systems (Ebrill et al 2001). There VAT is collected along with import duties on the first sale of a good and at point of import, and export rebates are paid on export. In the VAT case, there is an additional complication of ensuring that VAT is not paid on products used as intermediate inputs—a problem generally solved using the invoice-credit system. If a full BCA is desired, the less complicated challenge of ensuring that higher, carbon-tax inclusive prices guide decision making by both consumers and producers requires only two of the key elements of a typical VAT—the levy on producers and importers and the export rebate. In countries with a VAT system, the administrative mechanisms for ensuring compliance would already be in place. A BCA would, in fact, be simpler than a VAT because the complex system of credits needed to relieve producers of the burden of VAT on their inputs would not be needed.

Since VAT rebates from destination-based rebates have withstood concerns about consistency with WTO rules, it seems reasonably likely that WTO compatibility would not be a binding constraint for inclusion of an export rebate in a BCA. Questions of WTO compatibility must arise much more starkly with an import-only BCA, frequently described as a carbon tariff (Krugman 2021), than with a full BCA including an export rebate. A carbon tariff would be calculated without regard to WTO members’ commitments, inevitably leading to cases where WTO bindings are violated. If, by contrast, a full BCA, including an export rebate, is viewed as a tax on demand, it should be admissible as a tax collected on imports in addition to customs duties, just as VAT on imported goods is collected.

5. Global Impacts

The central question for this paper is whether conventional carbon taxes should be accompanied by full BCAs that convert them into taxes on demand for emission-intensive products. If all countries adopt a uniform ad valorem CT without a BCA, the global impact comes about because the tax reduces the prices received by producers relative to consumers. If all countries introduce CTBAs, the global impacts come about because the tax raises prices to users (not just final consumers but users of intermediate inputs as well) relative to producer prices. With all countries adopting the same measure, the traditional result that it does not matter for the overall outcome whether the tax is on demand or on supply (Gruber 2019) would be expected to hold, making the choice of a CT or a CTBA irrelevant. But the central problem under consideration is that some countries are willing to impose a CT while others are not.

The CT and the CTBA bring about their global impacts quite differently. A carbon tax directly reduces supply in the countries that impose it. If the set of countries is collectively large, this effect is offset by an increase in the world market price of the good which, in turn, results in higher output in non-participating countries—and leakage from the CT countries to their trading partners. By contrast, a full CTBA in a collectively large set of countries reduces the world price of the good and hence reduces the incentive to produce in both taxing and non-taxing countries. In this case, leakage arises because the lower world price stimulates demand in non-participating countries.

The vast array of work examining the impacts of potential BCAs using CGE models has incorporated a great deal of important and useful detail on key parameters such as elasticities and emission intensities. However, the large number of parameters involved makes it very difficult to examine the sensitivity of the results to key, simple parameter differences such as those between the slopes of the supply and demand curves in Figures 2 and 3. Because these key parameters are generated by combinations of parameters and shares, such as elasticities of final demand and demand for intermediate use; market shares of different products and elasticities of substitution between domestic and imported goods, it is difficult to experiment with them in a large scale model.

In the rest of this section, a very simple general equilibrium model is used to examine the importance of these elasticities in a model where market shares can change. This model, presented in the Appendix, includes two countries (Home and Foreign), two commodities (emission-intensive (E) and a clean numeraire). Initially both allocate 50 percent of their resources to production of E and spend 50 percent of their income on that good. Only the Home country imposes a tax—either a tax on production of the emission intensive good or a tax on consumption of that good. In the base case, consumer preferences are represented using a Constant-elasticity of substitution model with an elasticity of substitution of 0.3, while production technology is represented using a Constant-Elasticity of Transformation function with an elasticity of transformation of 2. Because these key parameters are readily changed in this model, it is very easy to assess the sensitivity of the results to changing them.

The results in Table 2 highlight the importance of the elasticity of supply relative to demand. Under the assumptions of the base case, the full CTBA is much more cost effective in reducing output of the emission intensive good than is a carbon tax on production. At a 10 percent tax rate, the CTBA is almost 4 times as cost effective as the carbon tax. The cost effectiveness of both measures declines as the tax rates go up, because the costs of these distortions rise as the square of their rate. But the cost effectiveness of the CTBA is still over three times greater with a CTBA than with a CT at a tax rate of 50 percent.

The cost burden on the home country—which imposes the tax—is roughly twice as high as on the rest of the world, which does not impose the tax. And this ratio stays broadly constant as the tax rate and the overall tax burden increase. If the home country were prepared to bear a burden of around 2 percent of GDP, it could achieve a reduction of 3.4 percent in global emissions with a CT or 5.7 percent using a CTBA. This result is a consequence of the assumption that demand elasticities are lower than supply elasticities for individual industries. It disappears once the elasticities of substitution are made equal at 0.9 in the last row of the table.

One troubling feature of the results in Table 2 is that none of them feature the game-changing reductions in emissions that appear to be needed to control rising world temperatures. Part of the reason for this is that this extremely simple model does not take into account the incentives created by carbon taxes to change techniques of production. However, if the typical elasticities of substitution between fuel and other inputs, such as 0.5, assumed in most CGE studies are anywhere near correct these effects will also be modest. This is an example of the challenge highlighted in Gautam et al (2022)—that it would extremely difficult to obtain the reductions in carbon emissions needed to control climate change without investing in technological changes that can both reduce emission intensities and increase productivity.

Table 2. Impacts of a Carbon tax vs a Carbon Tax and BCA, % changes

	Carbon Tax (CT)					CTBA				
Tax Rate	**Emis-sions**	**Global Income**	**Home Income**	**Wld Price**	**Em Redn/ cost**	**Emis-sions**	**Glob Inc**	**Home Inc**	**Wld Price**	**Em Redn/ cost**
10	-1.5	-0.2	-0.5	4.3	6.6	-1.3	-0.05	-0.1	-0.6	25.9
20	-3.4	-0.9	-2.1	8.6	3.5	-2.5	-0.18	-0.4	-1.2	13.5
30	-5.6	-2.2	-4.8	12.6	2.5	-3.6	-0.39	-0.8	-1.8	9.4
50	-10.9	-6.1	-13.0	19.4	1.8	-5.7	-0.95	-1.9	-2.9	6.1
$\sigma=0.3$, $\sigma_T=0.9$										
20	-2.7	-0.48	-1.1	7.8	5.6	-2.1	-0.17	-0.3	-2.4	12.5
$\sigma=0.9$, $\sigma_T=0.9$										
20	-4.9	-0.55	-1.2	5.1	9.0	-4.0	-0.41	-0.9	-4.5	9.8

Note: Reported emission changes reflect only output changes, ignoring incentives to change production methods resulting from the Carbon Tax.

6. Differentiated BCA Rates

Many proposals for CTBAs involve differentiated rates depending upon either the emission intensity of production in the exporting country, or whether CTs have been applied to that production. Hillman (2013) argues strongly that a BCA would likely be compatible with WTO rules as long as it was applied at a rate that did not exceed the tax rate applied on domestically produced goods. This rate is also consistent with the goal of compensating domestic producers for the costs imposed by the domestic carbon tax. Taxes based on foreign emission intensities may or may not compensate domestic producers for the costs associated with the CT they face.

As well as likely being incompatible with WTO rules, the approach of applying taxes that vary with foreign emission intensities faces enormous informational hurdles and risks of moral hazard. How would the authorities in the importing country assess the emission intensity of production in foreign markets? How accurate would the resulting measures be? Would the process become captured by domestic lobbies and result in disproportionately high barriers? To avoid this risk, perhaps estimation of these intensities might be put in the hands of a neutral, technocratic body. But that way lies a potential risk of a different form of capture, where foreign producers might convince the assessment body that their CT regime was strict when it is in fact toothless[2]. Another potential problem is shuffling, where production in the exporting country involves a spectrum of techniques with differing emission intensities, and those production units with low intensities were allocated to markets with BCAs. While this might comply with the importer's requirement, it might also have no impact on emissions.

Many proposals involve waiving the BCA on products produced in countries with CT regimes, to avoid double taxation of production in those countries. While understandable in a situation where only production CTs are available to policy makers, this proposal faces similar problems as proposals for BCAs levied based on the carbon intensity of products. What constitutes an emission regime comparable enough to the domestic CT for the duty to be waived? Is an ETS with free allocations of emission quotas comparable to a carbon tax? Once we move beyond CTs alone, there is another solution to the double taxation problem. If the exporting country imposes a full CTBA instead of a CT alone, the burden of the CT on its exports is relieved by the rebate at the point of export. Some exporters may continue to impose CTs on production of some of their products, perhaps for administrative convenience, perhaps out of a belief that without export rebates their production is unresponsive to prices, or perhaps out of a distributional preference. However, this decision would lie with the exporting government, rather than requiring a waiver of the duty in the importing country.

Not all countries would need to adopt CTBAs. A world in which some countries use CTs and some use CTBAs would allow mitigation of GHG emissions. Some of the mitigation would come from leftward shifts in supply functions and some from reductions in global demand. There would be some inefficiencies with some production being taxed in both the producing country and the importing country, but that inefficiency would result from the choice of the producing country to use a pure CT, rather than a CTBA. If full CTBAs became as widely popular as destination-based VATs (Ebrill et al 2001), the resulting inefficiency would be small.

One other type of differentiated rate proposal involves carbon clubs, where a set of countries set a common standard of carbon abatement and impose import BCAs on countries outside the club (Nordhaus 2019; Meyer and Tucker 2021). Clearly, such proposals would be likely to result in very serious political conflicts with excluded developing countries when, as noted by Lester (2021), it is today's industrial countries that are responsible for most of the stock of greenhouse gases driving the world's worsening climate crisis. These conflicts could become very serious if the implications for developing countries' opportunities for industrial development are as dire as depicted by Mattoo et al (2012). The support for these proposals arises from concern that CTs are not politically feasible. But

2 The intense problems with certification of products as organic (Parker 2021) perhaps point to potentially very serious problems with the much more challenging problem of measuring emission intensities in global production.

are full CTBAs really infeasible? Have they ever been tried? Surely it would be worth considering approaches like full CTBAs that can be implemented by individual countries without requiring international agreement and that are less vulnerable to "leakage" because they focus on less-elastic demand rather than product supply, before moving to exclusionary carbon clubs?

Conclusions

Many current proposals for Border Carbon Adjustments (BCAs) would focus only on import measures, would involve sharply different border adjustments by country and by product and could generate serious economic costs and risks of conflict between countries. Does this mean that the idea of using BCAs as a complement to carbon taxes or similar measures should be rejected? Not necessarily.

To see how BCAs might be designed in ways that avoid these problems, it is important to begin with a clear goal. Are they designed to deal with the competitiveness concerns of producers or to deal with "leakage"? It is clear that producers' concerns about competitiveness—and unequal treatment where they must pay a carbon tax not paid by foreign competitors—are a serious obstacle to implementation of carbon taxes and other measures to mitigate emissions. By contrast, as argued by Kortum and Weisbach (2017), leakage reduction is only very weakly related to fundamental economic concerns such as the cost of achieving mitigation of greenhouse gas emissions or to political economy concerns about competitiveness. There seems to be a strong case for focusing BCAs on dealing with competitiveness challenges and the cost of mitigating emissions rather than on mitigating "leakage".

This paper compares traditional production-based carbon taxes with carbon taxes buttressed by BCAs. It shows that, while the former are clearly taxes on production, the latter are taxes on use of carbon-intensive commodities. There are clear parallels with comparisons between origin-based taxes, such as income taxes, and destination-based taxes such as traditional VATs, with the important differences that CTBAs would involve different rates between commodities based on carbon intensity and would tax intermediate use as well as final demand. The approach suggested here would involve using full BCAs, applied through import charges and export rebates, to complement carbon taxes without requiring discrimination between trading partners. It would reduce both carbon leakage and the cost of reducing emissions by shifting the burden of the tax from supply to demand.

This paper uses simple diagrams to show that a combination of a carbon tax and a BCA, or a CTBA for short, increases the cost to users of products purchased domestically while allaying producers' concerns about competitiveness by relieving them of the cost burden imposed by the tax, and leaving in place the incentives for producers to change their production techniques in ways that reduce emission intensities. While production-based carbon taxes have proved extremely difficult to implement because of concerns about competitiveness, a CTBA may be able to solve those problems at national level and allow introduction of CTs with measures that deal with these direct competitiveness concerns. This approach would deal with the competitiveness concerns of producers in both importable and exportable sectors by setting BCAs based on the WTO's National Treatment principle of securing equal treatment for domestic and foreign goods.

A simple modeling exercise suggests that a full CTBA could substantially lower the cost of achieving any given level of reduction in greenhouse gas emissions when only some countries impose carbon taxes. This is because elasticities of demand for individual goods are lower than their elasticities of supply. In this situation, a consumption-based tax is being imposed on the less elastic side of the market, that is less vulnerable to "slippage" where the impact of the tax in one market on global demand declines because the share of that market shrinks as the tax rate rises.

An approach focused on taxing consumption rather than production of carbon could potentially avoid having to deal with the acute economic and international law challenges associated with having different border tax rates by country. If "leakage" is used as a motivating principle, it will be essential to differentiate BCA rates by supplier, based on evidence about the emission of production by country, and/or by production process in each country. Alternatively, countries attempting to use a “carbon club” approach will have to reach agreement on equivalence of mitigation measures within the club and impose punitive border measures against suppliers from the rest of the world, at risk both of igniting international tensions and of running afoul of international law. With a competitiveness focused approach using BCAs based on the cost of compliance with domestic measures, there is no risk of discriminating between domestic and foreign suppliers, and the measures are likely to comply with existing WTO rules (Hillman 2013).

Many of the same issues arise in agriculture if and/or when domestic measures are introduced to reduce emissions, such as emissions of super-potent greenhouse gases like methane from cattle or rice. A major challenge in agriculture is that most of these emissions are from production processes such as ruminant digestion that are much more difficult to monitor and control than emissions from combustion of fuels.

Appendix

Simple Model for Welfare impacts of CTBAs vs Carbon taxes

$ontext
This model has one commodity plus a numeraire, to assess the welfare implications of using either a production or a consumption tax in one country on global welfare. A key question is whether the welfare impacts are best described by the elasticity of demand/supply, or the combined elasticities of supply and demand.

```
$offtext
SETS
*Home and foreign ctries.  Emission and clean.  Numeraire and non
Ctry   /H,F/
Commod /E,C/
;

PARAMETERS
PN          Price of numeraire  /1 /
Beta1       Base supply share of commodity /0.5 /
Alpha       Base demand share of non-numeraire commodity /0.5 /
sigmat      Elasticity of transformation in production/ 0.9 /
sigma       Elasticity of substitution in demand /0.9 /
Q           Country resource endowments   /100/
TC(Ctry)    Consumption tax rate  /H 0, F 0/
TP(Ctry)    Production tax rate   /H 0, F 0/
U0(Ctry)    Base utility level    /H 100,F 100/
;

VARIABLES
PI          World price of good 1
SD(Ctry)    Supply of the good from each ctry
SDT         Global Supply and emissions
DD(Ctry)    Demand for good by each ctry
U(Ctry)     Utility level
EXP(Ctry)   Expenditure function
CPI(Ctry)   Consumer price index
Rev(Ctry)   revenue from production in each country
GREV(Ctry)  Govt revenue by country
GLOBEV      EV globally
;
*Initializing Variables
PI.L = 1;
U.L(Ctry) = 100;
CPI.L(Ctry) = 1;

EQUATIONS
   SUPPLY(Ctry)
   SDTOT
   DEMAND(Ctry)
   SD_Balance
   EXPDEF(Ctry)
   CPIDEF(ctry)
   REVDEF(Ctry)
   GREVDEF(ctry)
   UDef(ctry)
```

```
 GLOBEVDef
;

SUPPLY(Ctry)..  SD(Ctry) =e= beta1*(PI*(1+TP(ctry))/PN)**(sigmat)*Q ;

SDTOT..      SDT =e= Sum(Ctry,SD(Ctry)) ;

DEMAND(Ctry).. DD(Ctry) =e= alpha*(PI*(1+TC(ctry))/PN)**(-Sigma)*U(ctry) ;

SD_Balance..   Sum(ctry,SD(ctry)) =e= Sum(ctry,DD(ctry)) ;

EXPDEF(Ctry)..
EXP(ctry)=e=(alpha*(PI*(1+TC(ctry)))**(1-sigma)+(1-alpha)*PN**(1-sigma))**(1/(1-sigma))*U(ctry);

CPIDEF(ctry)..
CPI(Ctry) =e= (alpha*(PI*(1+TC(ctry)))**(1-sigma) + (1-alpha)*PN**(1-sigma))**(1/(1-sigma)) ;

REVDEF(Ctry)..
       Rev(ctry)   =e=        (Beta1*(PI*(1+TP(ctry)))**(1+sigmat)   +   (1-Beta1)*PN**(1+sigmat))**(1/
(1+sigmat))*Q;

GREVDEF(ctry)..
GREV(Ctry)  =e= TC(ctry)*PI*DD(Ctry) - TP(ctry)*PI*SD(Ctry);

UDef(ctry)..   U(ctry) =e= (REV(ctry) + GREV(ctry))/CPI(ctry) ;

GLOBEVDef..    GLOBEV =e= Sum(ctry,u(ctry)) ;

*Model

Model Effic_Cost     efficiency costs of consumer and Producer tax/ all  /;


Options  ITERLIM  =  1000,  LIMROW  =  50,  LIMCOL  =  50,  SOLPRINT=ON,  MCP=PATH,
NLP=CONOPT4, CNS= Conopt4
;

 SOLVE Effic_Cost Using CNS;

*Now solving with a tax on demand

 TC(“H”) = 0.2;

 SOLVE Effic_Cost Using CNS;

*Now with a Prodn tax-- last results are pdn tax

 TC(“H”) = 0.0;
 TP(“H”) = -0.2;

  SOLVE Effic_Cost Using CNS;
```

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