

**ECONOMIC / FISCAL INSTRUMENTS: COMPETITIVENESS ISSUES RELATED TO CARBON /
ENERGY TAXATION**

Annex I Expert Group on the United Nations Framework Convention on Climate Change

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FOREWORD

This Working Paper is one of a series of eighteen studies carried out under an Annex I Expert Group project on "Policies and Measures for Possible Common Action". The studies were written by the OECD, together with the International Energy Agency, for the Annex I Expert Group on the United Nations Framework Convention on Climate Change (UNFCCC). The goal of the project was to assess a range of cost-effective greenhouse gas mitigation policies and measures for countries and Parties listed in Annex I to the UNFCCC. The working papers served as analytical input to negotiations under the UNFCCC. The working papers may also be useful to national policy makers. The measures analysed do not necessarily represent policy preferences of Annex I Parties.

The project benefited greatly from substantial input from delegates. Three successive chairmen of the Annex I Expert Group provided outstanding leadership for the project: Doug Russell (Canada); Ross Glasgow (Canada); and Ian Pickard (United Kingdom). The work was supervised by Jan Corfee Morlot (OECD). Fiona Mullins (OECD) drafted the initial framework which was used to structure the eighteen working papers.

The Annex I Parties or countries referred to in this document refer to those listed in Annex I to the UNFCCC: Australia, Austria, Belarus, Belgium, Bulgaria, Canada, Czechoslovakia (now Czech Republic and Slovakia), Denmark, the European Community, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Lithuania, Luxembourg, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russian Federation, Spain, Sweden, Switzerland, Turkey, Ukraine, United Kingdom and United States. Where this document refers to "countries" or "governments" it is also intended to include "regional economic organisations," if appropriate.

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1. EXECUTIVE SUMMARY

Background and context

A previous study for the Annex I Expert Group on the UNFCCC examined issues related to carbon/energy taxation as a common policy to reduce greenhouse gas emissions among Annex I Parties.¹ Such taxation would serve to reduce energy-related CO₂ emissions by placing a financial cost on CO₂ emissions, thus creating an economic incentive to reduce carbon intensity in production processes and shift production to less carbon-intensive sectors. The study looked at experience with, as well as modelling results for taxes based on the carbon and/or energy content of different fuels, and explored the rationale for co-ordinated taxation within Annex I. Competitiveness issues, beyond the fossil fuel sector, were only discussed to a limited extent.

The study observed that: “Although energy expenditures amount to a relatively low percentage of Gross Domestic Product (GDP) within OECD economies (between 3 and 11 per cent on a purchasing power parity basis, with a 5.8 per cent average for OECD as a whole), energy-intensive industries would still lose competitiveness, all other things being equal, if other trade partners were not to adopt similar carbon/energy taxes”. The purpose of this paper is to further explore this last point, and assess the competitiveness effects of carbon/energy taxation, looking primarily at energy-intensive industries. In the discussion over the use of carbon/energy taxation, a principal concern is that such taxation would reduce the competitiveness of Annex I carbon-intensive exports and lead to leakage of emissions through increased production outside Annex I. Yet another question is the extent to which a uniform tax would or would not have the same effects on competitiveness among Annex I countries. This study tries to provide insights on these two issues.

The implications of carbon/energy taxation on fossil fuel activities and other distributional issues were covered in the previous Annex I Expert Group study. Also, this paper does not address the electricity sector.

Approach and methodology

First, the study presents different definitions of competitiveness and the notion of comparative advantage, central to international trade discussions. Recognising that competitiveness is a concept that best applies to firms but that firm-level analysis for the Annex I region is not feasible, the links between carbon/energy taxation and competitiveness are explored, based on the following material:

¹ The executive summary of the previous taxation study is provided as an appendix to this study.

- Statistical observations related to the magnitude of trade in energy-intensive products from and to Annex I, with a focus on the three OECD regions;²
- An original analysis of static cost increases caused by a US\$ 100 tax per tonne of carbon for the main energy-intensive industries, in a selection of OECD Member countries,³
- A review of empirical analyses dealing with the links between environmental regulation and trade patterns;
- A review of model-based analyses of GDP effects of carbon/energy taxation with a focus on competitiveness and the issue of leakage. These models are either long-term global general equilibrium models or short- to medium-term macro-economic models of national economies.

The study then provides an overview of possible compensatory measures, as they are currently implemented to deal with competitiveness concerns in countries where carbon/energy taxes have been introduced. Other compensatory measures analysed in the literature are also discussed.

Lastly, the study offers a general overview of industrial competitiveness issues. Competitiveness concerns related to carbon/energy taxation should be measured against this broader set of issues.

Results and observations

Competitiveness and taxation: a few orders of magnitude

Energy-intensive industries (paper and pulp, chemicals, excluding refining, and basic metals) account for about 3 to 6 per cent of GDP and smaller shares of total employment in OECD Member countries.

One can start from the observation that the magnitude of the competitiveness effects of co-ordinated carbon/energy taxation in Annex I depends, among other things, on:

- the contribution of trade in carbon/energy-intensive products to gross domestic product (GDP); and
- the proportion of trade in carbon/energy-intensive products with non-Annex I countries in total trade, and the extent of competition from non-Annex I country exports.

Statistics on the contribution of total trade to GDP show that OECD Europe economy is more dependent on trade than North America and OECD Pacific. In 1994, the OECD regions' trade in energy-intensive

² In this study, energy-intensive products include: iron and steel, non-ferrous metals, chemical products (excluding refining) and paper and pulp; "OECD Europe" does not include countries with economies in transition which recently joined the OECD; "OECD Pacific" is: Australia, Japan and New Zealand; "North America" is the United States and Canada.

³ This tax level was chosen by the authors of the study for illustrative purposes; it does not imply any specific target or timetable for reducing carbon emissions globally, among Annex I countries, or for any country individually.

products with non-Annex I countries amounted to 3 - 7.5 per cent of total exports, and 1 - 4 per cent of total imports, the lower shares being for OECD Europe and the higher for OECD-Pacific, in both cases.

Industrial energy prices, energy and carbon-intensities (per unit of value added) vary widely across industries and countries. A uniform tax would reduce the variability of industrial energy prices across regions, but would also result in different increases in production costs. For energy-intensive industries in most of the selected nine OECD Member countries, a US\$ 100 per ton of carbon tax would result in a static cost increase of about 2 per cent.⁴ For sectors and countries in this analysis, estimates range from 0.6 to 11 per cent.

Shortcomings of the above results include the following:

- situation of individual countries within the three OECD regions differs significantly from aggregate regional observations;
- it does not account for the full pass-through of the tax in the economy, which would result in somewhat higher prices for other intermediary inputs to these sectors;
- it does not capture possible macro-economic effects of the tax such as inflation, its effect on the economy as a whole and on energy-intensive sectors in particular; moreover, no assumption is made about how the revenues of the tax would be recycled;
- it does not allow for adjustments of production processes, in response to the new price levels, nor does it incorporate real-world elements of such a tax (e.g. the possibility of phasing in);
- it does not render the various levels of possible energy efficiency improvements, likely to differ within the same industrial sector across countries, since their prevailing industrial energy prices are quite disparate;
- it does not indicate whether or not the position of industries/countries with respect to their price competitiveness would be altered by such a tax;
- the comparison of static cost increases for energy-intensive industries across countries does not give a full picture of the competitiveness impact at the firm level, as profit margins differ, allowing for more or less costly adjustments in output prices.

Limited data precludes the same analysis of this issue for countries with economies in transition; currently low energy price levels suggest that a uniform Annex I wide tax would have more drastic impacts on the production structure of industrial activities.

Descriptions of international markets for iron and steel, aluminium and nitrogen fertilisers are provided, laying out key determinants in the formation of these markets and the potential effects of taxation in that context.

⁴ These figures assume that all energy use is taxed, including non-fuel uses of energy. The study also looks at cost increases assuming that non-fuel energy use is not taxed, as it does not directly result in CO₂ emissions. Cost increases are up to 40 per cent lower in that case.

Results from empirical and model-based analyses

The links between environmental regulation and trade have been the subject of much economic literature. Empirical analyses have tried to evaluate the effects of different levels of stringency in environmental policies on trade patterns. A statistical analysis to test the hypothesis of links between environmental regulation and trade in pollution-intensive products concluded that “*the important and consistent finding of the empirical tests was to show that the hypothesis that environmental regulations alter patterns of world trade is not supported empirically*”.⁵ Another study focused on American competitiveness finds that “*Although the long-run social costs of environmental regulation may be significant, including adverse effects on productivity, studies attempting to measure the effect of environmental regulation on net exports, overall trade flows, and plant location decisions have produced estimates that are either small, statistically insignificant or not robust to tests of model specification*”.⁶

These results do not provide a direct indication of the effects of carbon/energy taxation on trade patterns in energy-intensive industrial products. Indeed, taxation differs from more standard command-and-control policies applied for pollution control so far: while providing a signal to develop most economic options to reduce emissions, it also applies a permanent cost on the remaining emissions. It is therefore difficult to conclude from these past experiences.

For the most part, attempts to estimate the effects of carbon/energy taxes on trade have relied on economic models. The question of leakage, that is, the increase in emissions from regions where the tax is not applied, has been studied by global general equilibrium models, albeit with little sectoral detail. Realistic leakage rates vary between slightly negative to 35 per cent. Highest rates are found in models where traded goods are considered homogenous, i.e. price is the only source of competitive advantage, whereas models which account for intra-industry trade, a common feature in observed trade patterns, usually find smaller leakage rates.⁷ Models rely on different assumptions of exchange rates adjustments and capital mobility, which are also crucial in estimating leakage rates.

Macro-economic models based on econometric analysis, best equipped to incorporate real-world features for short to medium run (1-10 years) analysis of policy changes, generally show small impacts on trade flows from the imposition of carbon/energy taxation. Importantly, finding the best option to recycle tax revenues would help reduce the negative competitiveness effects of carbon/energy taxes, and potentially improve the competitiveness of less energy-intensive sectors of the economy.

Both types of models have specific methodological shortcomings which prevent using these results on competitiveness in any predictive fashion.

Compensatory measures

In practice, carbon/energy taxes have all been introduced unilaterally with some form of exemptions for energy-intensive or trade-exposed activities, to accommodate competitiveness concerns, mostly because other trade partners have not adopted similar measures. For any compensatory measure, the issue is

⁵ Tobey (1993, in Adams, 1997).

⁶ Jaffe *et al.*, (1995).

⁷ Intra-industry trade means that a country or region can be both an importer and an exporter of a given product. This reflects the role of non-price elements in international competitiveness, as well as intra-firm trade of multinationals, among other factors.

whether potential competitiveness effects of taxes can be alleviated by policies without altering the environmental goal (reductions in greenhouse gas emissions).

Appropriate recycling of tax revenues to the productive sector would help reduce the negative effects of the tax on energy-intensive sectors. Investment tax credits or funding for energy efficiency improvements could also be granted to energy-intensive sectors. Other options include progressive carbon tax rebates that limit the tax burden but still encourage lower emissions, or tax rebates with the threat of a full payment of the tax if certain agreed emission limits are not met by the company/sector.⁸ It is often suggested that competitiveness problems from carbon/energy taxation can be minimised through border tax adjustments. Border tax adjustments are currently under discussion and study by the World Trade Organisation and the OECD with respect to their legal requirement and practicality.

Synthesis

Any analysis of the competitiveness issues related to taxation can only arrive at limited findings, as it deals only with the price element of competitiveness, whereas a number of non-price elements intervene in companies' choices on production methods, mix of products, investment decisions including the location of new capacity and sources of inputs.

This study clarifies the notion of competitiveness in the context of taxation, but mostly illustrates orders of magnitude which help assess the importance of this question for different regions: the contribution of trade in GDP, the share of trade in energy-intensive products with non Annex I, and first-order estimates of cost increases resulting from a tax. Beyond the fossil fuel sector, not covered here, only a few sectors in certain countries would face significant cost increases in the short term. Longer-term estimates are less reliable, as little is known about ongoing structural changes (e.g. lower steel use per unit of GDP in OECD) and the rate of diffusion of more energy-efficient processes (e.g. secondary aluminium). Above all, compensatory measures may help alleviate such effects.

At the end, cost increases from carbon/energy taxation ought to be compared with other factors affecting price levels such as exchange rates variations and cyclical variations of stocks, which sometimes lead to dramatic increases/decreases in world prices of basic metals. In other words, changes in the international markets of energy-intensive products may well dwarf the price effects of a tax.

Similarly, competitiveness is an issue that goes much further than the concerns of energy-intensive activities faced with carbon/energy taxation. For example, the study does not consider that carbon/energy taxation could have a positive effect on competitiveness of countries if less energy-intensive sectors are considered. OECD governments strive to improve companies' competitiveness through reduced factor costs (e.g. on capital and labour through tax shifts), improved productivity, and strengthened infrastructures. In particular, disparities in labour costs currently dominate international trade discussions. In each country, policies aiming to improve companies' competitiveness will have to balance specific sectoral concerns with more wide-ranging national priorities.

⁸ Emission limits could be introduced through voluntary actions or in a system of tradeable emission permits.

2. COMPETITIVENESS: DEFINITIONS AND THEORETICAL IMPLICATIONS

This paper examines some of the competitiveness issues concerning carbon/energy taxation in Annex I. The rationale is that by placing a financial cost on the emissions of carbon to the atmosphere, an economic incentive will be created that will serve to reduce carbon intensity in production processes and to shift production to less carbon-intensive sectors. Such a tax is usually seen in agreement with the accepted “Polluter Pays” seems to dominate policy discussions - usually focusing on how environmental taxes increase costs of affected industries and thus reduce their economic performance. From an international perspective, this argument takes the form that the additional costs incurred by the affected industries will lead to a loss in international competitiveness if not all trade partners take similar measures. This loss in competitiveness would translate into a decline in net exports and perhaps even the relocation of these industries, thus having a negative impact on GDP and employment, and less than anticipated effects on global emission levels.

As environmental benefits from global actions are difficult to quantify, public discussion often centres on their potential negative economic effects. This focus on costs also stems from the fact that cost implications to affected parties appear more straightforward and that these parties are clearly identified. Furthermore, as the environmental benefits of emission reductions accrue over a long period of time and are often widely dispersed, to measure and credit the benefits to the costs is quite difficult - a factor that is particularly true for global environmental issues. Such difficulties make traditional cost benefit analysis problematic for global actions and thus tend to focus debate on the cost side only.

For those countries which consider it necessary to pursue carbon/energy taxation domestically, the concern about the effect on international competitiveness is one of the reasons to consider co-ordinated carbon/energy taxation.

Due to its dynamic and subjective context, competitiveness is difficult to define. Further, competitiveness is closely linked to the concept of comparative advantage. Countries are competitive in those goods which they have a relative advantage in producing. Comparative advantage can result in a country exporting a good which it is not absolutely more efficient in producing, as long as it is relatively more efficient at producing that good compared to others it can produce. Comparative advantage is often related to the country’s factor endowments, such as its labour force, natural resources, and capital stock.

In this paper, the term competitiveness is used to mean the degree to which firms can maximise this comparative advantage, specifically in international trade. Thus the cost structure of firms, as well as other “micro” factors such as product quality, service and logistical networks, affect a firm’s competitiveness. Further competitiveness is directly affected by “macro” factors such as exchange rates and trade regimes. New carbon/energy taxation would affect competitiveness through direct increases in the affected firms’ cost.

The climate change benefits within Annex I are realised by the carbon reduction caused by the tax-induced shifts toward less carbon-intensive industries and sectors. Conversely, to the degree the tax causes a shift of production of carbon-intensive goods outside the Annex I area, carbon leakage would

offset the environmental benefits of reduced carbon emissions in Annex I. Thus the issue of changes in competitiveness is crucial to understand both the economic and global environmental impacts of a carbon/energy tax.

Box 1. Comparative Advantage

From an economic standpoint, *comparative advantage* is the traditional driving force for international trade. While clearly a powerful theory, its utility in public debate has been limited because, as Krugman (1995) points out, “*almost nobody understands such an abstruse concept as comparative advantage.*” Nevertheless, defining the concept serves to illustrate its relationship to competitiveness. Jaffe (1995) defines comparative advantage as: “*countries export those goods and services that they make relatively (but not necessarily absolutely) more efficiently than those of other nations, and import those goods and services they are relatively less efficient in producing.*”

Comparative advantage is usually assessed at the country level. Efficiency is determined by how many factors (labour and capital) are used in the production of a good and these efficiencies are compared across countries. Thus, the comparative advantage goes to the country that produces the output with the least relative cost of inputs. Monetary costs and prices in this model are considered to be flexible and secondary to the real inputs (Dornbusch, 1980.)

Competitiveness is derived from this concept and is often used to mean how relative costs and prices influence trade while not necessarily altering the actual factor inputs in production. For example, the amount of energy used to produce steel is not affected (initially) by a carbon/energy tax, but rather by the cost of such energy changes and thus alters the production costs in Annex I countries.

On the subject of competitive advantage and comparative advantages, OECD notes that “*relative productivity progress, which is sometimes designated as the main source of national wealth, does have an impact in trade-exposed sectors only (mainly) when full employment of factors can trigger international specialisation based on comparative advantage. In circumstances of under-employment, trade-exposed firms’ absolute competitive advantage determines their factor employment and factor income levels*” (1996b, p. 13).

Competitiveness and taxation

Competitiveness can be viewed at several levels - national, industrial, or firm - as well as domestically and internationally. As both national and even industry comparisons are based on aggregate measures, the clearest analytical way to look at competitiveness is at the firm level. Here competitiveness is defined as the firm’s ability to maintain or increase market share based on its cost structure, quality, or other perceived attribute (such as a trademark or service network).⁹

While often brought forth in debates, the concept of a *country’s competitiveness* is often ambiguous. The World Economic Forum defines competitiveness as “the ability of a country to achieve sustained high rates of growth in GDP per capita.” The International Institute for Management Development’s definition is “the ability of a country to create value added and thus increase national wealth by managing assets and processes, attractiveness and aggressiveness, globally and proximity, and by integrating these relationships into an economic and social model” (both citations taken from Adams, 1997). A recent Norwegian public expert report uses the definition “the country’s ability to ensure the highest possible remuneration of production factors in the society, given full employment and long-term balance in the current account” (NOU, 1996).

⁹ In this paper, the theoretical analysis is done at the firm level, but as statistics exist at the national and industry level, the empirical analysis is done at these levels.

Industrial competitiveness is generally viewed as an industry's ability to export its goods, with industry being defined as a group of firms that produces similar goods. However, an industry is often very heterogeneous in what it produces, in how it produces it, and to whom it sells. For example, a chemical industry produces a wide range of chemical products, some of which are traded internationally and others only domestically. In some industries, such as sulphur, the means of production (mining or a by-product of refining) are entirely different and the cost functions completely independent. Finally, the market can be segregated, as in the case of cement, where the cost of transportation circumscribes the scope for international trade. The result of such heterogeneity is that the impact of a carbon/energy tax can have wide variation among firms within the same industry.

Ultimately, the *competitiveness of the firm* is the most precise level to evaluate the potential effects resulting from a carbon/energy tax. In the sense that a firm produces goods and sells them into the market, its ability to maintain or increase its market share and profitability reflects its competitiveness and that of both the industry and the nation.

Faced with a carbon/energy tax, a firm has five options, not all of which are available to all firms in all sectors. First, if the tax is not significant to the firm's cost, the effect is minimal and operations are little affected. Second, if the firm acts as a price-maker, it can shift the cost to its customers. Third, the firm can modify the production of its products to reduce the carbon intensity, notably via substitution of lower carbon-intensive inputs and/or introduction of more carbon efficient processes. Fourth, the firm can relocate production to where it is not subject to the tax. Or finally, it can cease operations.

Competitiveness (in terms of the ability to maintain or increase market share) results from many factors (such as technical efficiency, labour, product quality), and the effect of a carbon/energy tax is reflected in the firm's cost structure. Holding everything else constant, the change in competitiveness will be determined by differences in factor prices, the firm's ability to minimise the cost impact from the tax, and the impact of the change in the various firms' costs on relative product prices.

In many ways, the ability to adapt to changes in factor prices is a measure of the firm's ability to compete. As a carbon/energy tax is a permanent increase, the firm's ability to adapt relates mainly to its ability to minimise the carbon content in its products or to avoid such a tax via changing the location of production.¹⁰ To the degree that the new tax reduces profitability, the firm's return on investment declines, thereby encouraging a shift of investment in other activities.

Depending on the firm's cost structure and adaptation, competitiveness is affected both domestically and internationally. *Domestically*, these impacts include:

- changes in the market shares and profit margins of firms within the domestic industry, including from increased competition from imported goods;
- changes in the return on investment and thus a potential shift of production between different firms or industries (or sectors).

Internationally, the two most direct measures will be reflected in the firm's ability to maintain its export markets. Thus, the impact of a carbon/energy tax will be shown by:

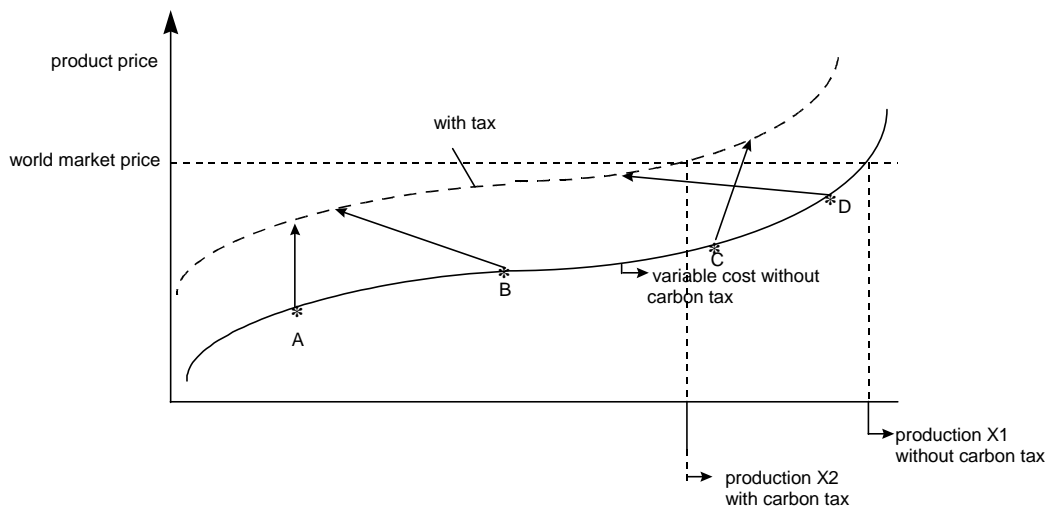
¹⁰ Here, we only look at how a firm limits the change in the costs of using the affected factor (fossil energy). But the firm may also change its mix of factors (e.g. labour, capital, other intermediary inputs) to minimise the overall cost increase.

- a change in the firm's market share and profit margin of its exports,
- its influence on the location of new production facilities.

Effects on firms' cost structure: an illustration

Internationally, an Annex I carbon/energy tax affects the competitiveness of carbon-intensive exports and imports via the cost change that the tax induces vis-à-vis non-Annex I firms. While that level of change depends on the factors discussed, the immediate short-term effect will almost certainly be an increase in the comparative cost of carbon-intensive goods in Annex I and thus a short-term loss in competitiveness.

Figure 1. Salter Diagram of a Hypothetical, Carbon-Intensive Industry



The competitiveness of goods, however, changes over time. In the short-term as capital equipment and the production process is relatively fixed, competitiveness stands a greater possibility of declining. Thus the initial effect will be determined by how sensitive individual firms are to these costs. If margins are sufficiently robust, a firm can choose to absorb a part of the incremental costs and to maintain market share. If margins are low, the likelihood is that market share will be lost.¹¹ Figure 1 illustrates the short-run impact of a carbon/energy tax on Annex I carbon-intensive industry.

The Salter diagram shows an industry's stylised cost structure - i.e. the firms ranked by their rising unit marginal cost.¹² This brief analysis offers an illustration of how firms within the same industry can have very different costs of production and responses to a carbon/energy tax. In the figure, the solid curve is the industry supply curve before the tax is levied, and the dotted line is this curve after the tax. This tax-induced shift has two major effects:

- the competitive position of the firms within the same industry changes based on their carbon intensity;
- the total industry output decreases.

¹¹ It is important to distinguish between a price-taker who will lose profit equivalent to the cost increase and a firm with market power which can pass these costs to its clients, albeit at some loss of sales

¹² See Johansen (1971).

For illustrative purposes, assume that the Salter diagram represents steel producers within Annex I and that each producer has a different marginal cost due to different technical efficiency, initial relative factor prices, and fuel mix (and thus carbon intensity). These variations have different tax impacts on the various firms, and shift the competitive rankings accordingly.

If one assumes that “C” and “D” are relatively inefficient steel producers, with “C” using only coal for fuel while “D” uses natural gas, the effect of a carbon/energy tax would be to increase the cost of the coal-based producer by more than the gas-based - thus reversing their competitive rankings in the short run. **As illustrated in Figure 1, “C” faces post-tax costs above world market prices, and would either need to undertake significant investments to shift to a more efficient process, cease operations, or consider relocation outside of the Annex I region.** Likewise, efficient producers “A” and “B” can be viewed as using electric arc steel technology, where the change in costs depends on the fuel mix for electricity supply. For example, the electricity supply for “B” is less carbon intensive (due to a higher proportion of hydro or nuclear) than “A,” and thus the competitive advantage of “A” is reduced relative to “B”.

Given (the simplified assumption) that world market price and thus demand does not change, production in Annex I will decline from X1 to X2. Non-Annex I producers will obtain a relative cost advantage and increase their production by an amount corresponding to the reduction in Annex I output. If non-Annex I supply is not perfectly elastic, the world market price will increase and modify though not offset the results displayed in Figure 1.

Further, not all firms in Annex I lose market share or suffer from lower margins. Rather, the relative competitive position of the firms before and after the tax change will indicate “winners” as well as “losers.”

It is useful to contrast this result with a value added tax of the same average magnitude. In the case of an *ad valorem* value added tax, the supply curve would shift upward, as in the previous case, and supply would fall accordingly, but the competitive rankings of individual firms would not change.

In the longer term, however, the cost effects (both internal and external to Annex I) tend to diminish. As capital is replaced and the production process adapts, new technology, process changes, factor substitution and such will act to reduce the carbon intensity of affected firms.

Importantly, the heterogeneity among the same **energy**-intensive industries means that the tax impacts will not be uniform, either within or outside Annex I. Some Annex I countries/industries may lose a lot, some less and some may gain. The position of certain countries or firms within countries as price makers (or price takers) is also an essential element. These impacts are based on the following considerations:

- If Annex I firms on the whole have higher fossil energy costs than their non-Annex I competitors, they will lose competitiveness to non-Annex I firms and the global price may increase. Non-Annex I firms will earn a higher profit (since their costs are not affected); some Annex I firms may enjoy higher profit if their carbon intensity is relatively low.
- If Annex I firms have a relatively low carbon intensity and variable energy costs, both profit and output will be only somewhat affected, but the (global) product price will not increase and non-Annex I firms will not increase profits.

These two points are closely tied to the degree to which energy efficiency (and other productivity improvements) can mitigate the impact of a carbon/energy tax in Annex I on overall cost. There could be

substantial variations in the effects of such a tax among countries before full capital stock and behaviour can adjust to the new price environment.

Effects on Firm's Investment Location

In the longer term, the firm has the option to locate production outside the taxed area - i.e. to a non-Annex I country. Presumably, such a response would be related to an inability to reduce the carbon-related costs in its production function¹³ and the resulting loss of market share and/or profitability *vis-à-vis* competing firms. Thus, the rate of return for new investment would be higher outside Annex I.

While such an option might appear to be extreme, a large proportion of international trade of intermediate products is within the production cycle of individual multinational companies. Therefore, such costs could affect new investment decisions. In addition, the recent advances in reducing the barriers to trade (e.g. WTO, NAFTA) further facilitate such a decision.

How changes in costs of production effect investment, however, is a more complex issue than measuring the change in cost structure of goods. Certain firms may be on the margin of relocation to increase profitability, and could take such a decision if a new tax were introduced (see firm "C" in above example). Yet other factors would be at play.

Studies reviewed by Adams (1997) tend to show that factors other than environmental costs¹⁴ are the primary determinants for location decisions: political stability, size and growth of potential market, access to other markets, labour costs, ease of repatriation of profits, transparency and predictability of administrative and legal framework, cultural affinity, infrastructure, quality of life, etc.

A study of United States outward investment shows that other key determinants are so-called "agglomeration economies" (i.e. infrastructure quality, degree of industrialisation and level of existing foreign direct investment); labour costs and market size being the next two important factors, while corporate tax rates are not critical in investors' decisions (Wheeler and Mody, 1992, in Adams). Another study by Krueger (in Begin *et al.*, 1993) also showed very little impact of environmental costs on investments under the North-American Free Trade Agreement. Results on the links between environmental regulation and trade are summarised further in Section 4.

Eventually, it is also important to separate the effect which a carbon/energy tax might have on industrial relocation from the bigger picture of global trends in industrial structure, and the evolution of global markets and technologies.

¹³ Or more specifically, this means that relocation outside Annex I would be more cost-effective than any option to abate emissions in an effort to minimise the tax burden at the current location.

¹⁴ In this case, the cost of complying with environmental regulations.

3. EMPIRICAL ANALYSIS

This section offers original analysis of the effects of an illustrative carbon tax on competitiveness for a selection of OECD Member countries. The approach used here aims to shed some light on the orders of magnitude of the competitiveness effects of a carbon tax. In the previous sections, we noted that the company level is most appropriate to look at the question of international competitiveness; unfortunately, such an analysis for the Annex I region is beyond the scope of this paper. Instead, we rely on available data to provide an objective view of the position of different OECD Member countries, and relevant industries in these countries. Unfortunately, the lack of reliable historical data for countries with economies in transition prevents us from integrating them fully in the present analysis; hence this analysis is limited to the OECD region, although main insights would apply to countries in transition, once their economies become more stable.

Rather than a modelling approach, we relied on statistical observations of the following elements, considered essential in a discussion of competitiveness and carbon/energy taxation:

- What sectors would be most affected by a carbon tax (apart from the fossil fuel sector)?¹⁵
- How big a share of overall trade do these sectors represent in OECD regions? Is this trade taking place mostly within the OECD/Annex I region or outside Annex I?
- What would be the short-run, static, effects of a US\$ 100 carbon tax on the overall production costs for these activities, i.e. what would be the effects of the tax on their *price* competitiveness?

We then describe the situation of three sample industries (iron and steel, aluminium, nitrogen fertilisers) to illustrate other elements of international trade that are relevant for competitiveness, including the relative weights of regions in world trade, ongoing technology diffusion, and general market conditions.

Carbon/Energy Intensity in Manufacturing

Overview of the Manufacturing Industry¹⁶

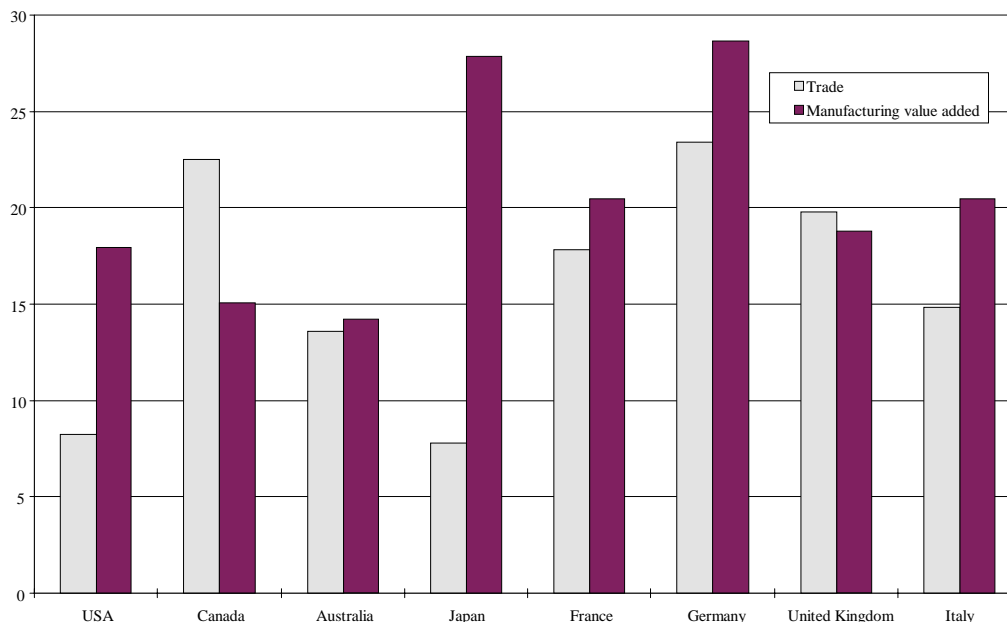
This section looks at the carbon/energy tax effect in manufacturing. This sector is highlighted because: 1) this is where most data and studies to date have concentrated and thus the most research exists, and 2) this is the area where the public debate has been the most pronounced. Yet, while attention has focused on carbon-intensive, manufacturing industries, a carbon/energy tax would be felt throughout the economy and would impact almost all manufacturing exports. Sectors such as Food and Beverages and Machinery are increasingly exposed to international competition, and if unable to pass the tax to the product prices,

¹⁵ See OECD (1995) for a discussion of the effects of climate change policies on fossil fuel activities.

¹⁶ Details about data sources and computational procedures are given in Appendix I.

their profit margins could erode. Other non-manufacturing industries could also be significantly impacted including such diverse sectors as energy-intensive mineral extraction and some types of agriculture.

Figure 2. Merchandise trade and manufacturing value added (per cent of GDP)



1) Average of exports and imports of physical goods

Source: UN-World tables, 1992.

In general, a country's competitiveness under a carbon tax would depend on the combination of the following factors:

1. the size of its industrial sector;
2. its level of trade; and
3. the carbon/energy intensity of traded goods.

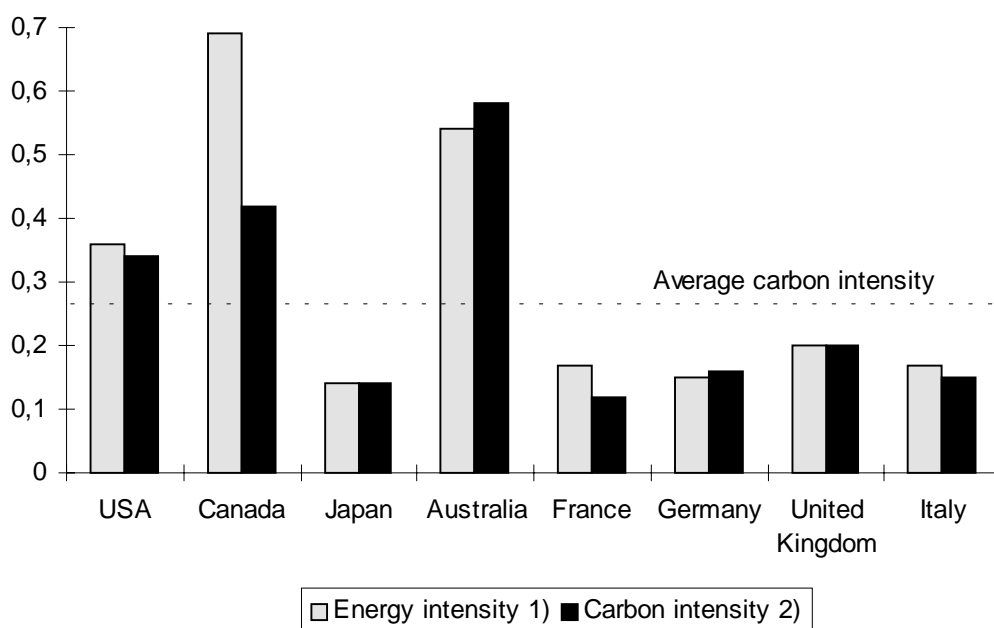
Figure 2 shows the variance among OECD Member countries on the first two of these factors: trade as a component of GDP shows greater fluctuation than the GDP contribution of industrial activities. Such a result is unsurprising in that the OECD Member countries are by definition industrialised and have relatively large industrial sectors, while trade varies based on the size of the domestic economy, trade orientation, and trade regimes.¹⁷ The contribution of trade to GDP differs widely across OECD regions: it is highest for OECD-Europe (27 per cent), and smallest (9 per cent) for OECD-Pacific. In North-America (Canada and the United States), trade represents 13 per cent of GDP.¹⁸

Within OECD Member countries, differences in carbon/energy intensity have greater variances than the first two factors. Figure 3 shows energy and carbon intensity the industrial sector.

¹⁷ See Baron *et al*, (1996), figure 14 in section 4.1.5 for the share of trade in GDP in all OECD Member countries.

¹⁸ These statistics include all countries within the 3 regions, not only countries selected for this analysis.

Figure 3 Energy and carbon intensities³ in total industry - selected OECD Member countries



1) Kilogram oil equivalents per US\$ value added

2) Kilogram of carbon per US\$ value added

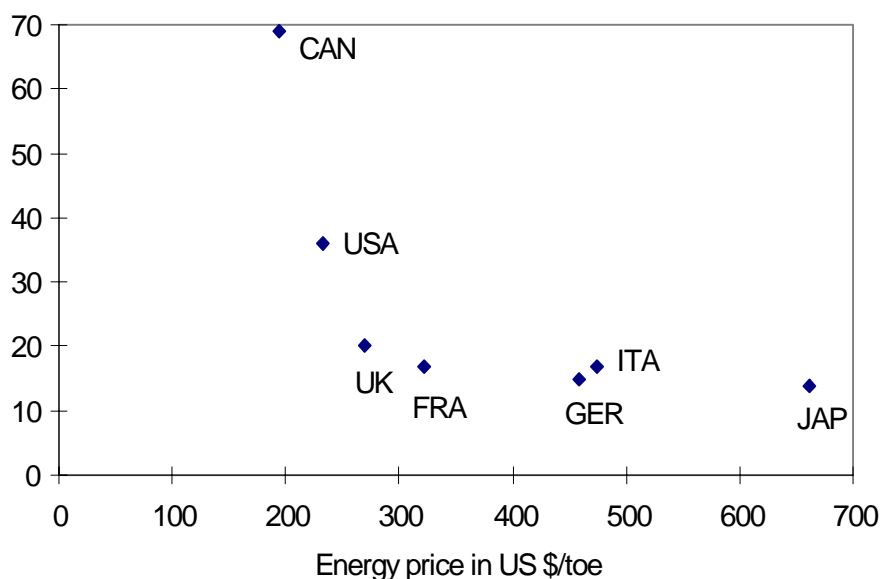
3) Carbon intensities are from direct use of fossil fuels (incl. feedstock) in industry, but not process emissions i.e. from use of coke in aluminium production. Carbon intensity includes derived carbon emissions in electricity generation.

Source: IEA/OECD, 1992 data

Measures of intensities at the country level obscure the differences among industrial structures; moreover, international comparisons should always be considered with care as they are based on exchange rates; as a result, the picture may differ from one year to another. Still, they show the wide variation in energy intensity and carbon intensity among national industries, a preliminary indication of the diverse effects of carbon/energy taxation in different countries.

The lower level of energy and carbon intensities in Japan and OECD Europe as compared to North America and Australia is partly explained by differences in fossil energy resources and energy price levels. Japan, a country with very limited domestic fossil fuel resources, has industrial energy price levels 2 to 3 times the OECD average. European industrial energy prices are on average 70 per cent above the level in North America. Without drawing further conclusion, Figure 4 illustrates the relationship between energy price levels and energy intensity for a few OECD Member countries.

Figure 4. Average industrial energy intensity¹⁾ vs. energy prices - Selected OECD Member countries



1) in kilograms of oil equivalent per US\$ value added.

Source: IEA/OECD, 1992 data

Overview of the energy-intensive industry

While the effects of any carbon/energy tax will be felt throughout industry, clearly the greater the carbon intensity, the greater the effect. Thus, attention has focused on those industries most affected - i.e. energy-intensive industry. Lacking data on individual firms, industrial statistics for individual countries and carbon intensities of specific sectors can be used as a proxy for how a carbon tax would impact the cost structure of firms, i.e. the change in the cost structure indicates potential competitive shifts among companies competing in regional or global markets.

An overview of the size (in GDP and labour terms), and carbon- and energy-intensities of energy-intensive industry in major OECD Member countries is shown in Table 1.

Table 1. Selected OECD Member countries, Energy-Intensive Industry

	Share of total industry, %	Share of GDP, %	Share of labour force, %	Energy ²⁾ intensity	Carbon ²⁾ intensity	Energy intensity Total industry
USA	25	4.5	2.8	0.80	0.75	0,36
Canada	26	4.0	3.1	1.85	1.11	0,69
Japan	23	6.3	2.7	0.38	0.37	0,14
Australia	26	3.7	2.6	1.30	1.57	0,54
France	22	4.1	3.4	0.52	0.40	0,17
Germany	23	6.8	2.9	0.41	0.42	0,15
United Kingdom	24	4.3	3.3	0.51	0.47	0,20
Italy	22	3.7	1.3	0.50	0.50	0,17

1) We have defined energy-intensive industry as (ISIC codes) 341 Paper and products, 35 Chemical industry (excl. 351, Refining), 37 Production of basic metals.

2) See footnotes in Figure 3.

Source: IEA/OECD, 1992 data.

An important distinction to make while looking at the above table is that energy intensity is not necessarily a reflection of how efficient a sector is *vis-à-vis* the same sector in another country. For national statistics, energy intensity and energy efficiency are usually, but not always, closely related. Given the production process, a firm or industry can be very efficient from a technical standpoint and still have high energy intensity. Utilising resources in the best possible manner does not necessarily imply using less energy per unit of output.¹⁹ If an economy has an unusually high proportion of such industries in the overall national statistics, the high energy intensity need not imply low energy efficiency.

Independent of energy intensity, the greater the industrial carbon intensity, then the greater the cost increase from a carbon tax in the short run. The degree to which this cost increase impacts competitiveness is also a function of the industry's (or the country's) market power - i.e., the degree to which capacity is concentrated among a few producers. Further, the less elastic product demand, the greater the scope for exerting market power. Thus, in the short-term, the degree that competitiveness is affected depends on both the relative carbon intensity of production and market power.

Energy-intensive industry constitutes approximately 20 to 25 per cent of total industry in all countries shown, although the variance of the shares of GDP and employment is much higher, reflecting the variance of the GDP share of overall manufacturing between countries. While variations exist, countries with a high energy-intensity tend to have a high carbon intensity as well (Australia, Canada and the United States, as opposed to European Union countries and Japan). Variations are largely due to differences in fuel mix - especially if the industry consumes a large percentage of electricity, since the carbon intensity of power generation varies greatly from one country to another.

Considering the countries in Table 1, Japan and Germany display the highest GDP share of energy-intensive industry (above 6 per cent) while also exhibiting relatively low energy intensity (due to higher energy efficiency) and low employment levels (less than 3 per cent). This level of energy intensity can be partly related to conservation efforts due to energy prices higher than the OECD average, and also to a high degree of automation (as indicated by the comparatively low employment ratio). France, Italy, and the United Kingdom represent a middle range of countries having higher energy/carbon intensities. The energy/carbon intensities appear closely tied, especially in the energy-intensive sector, perhaps reflecting similar industrial and energy cost structures.

One reason for differing carbon intensities of goods from sectors labelled as "energy-intensive" is the nature of these goods within the sector: semi-finished, finished products, or consumer goods. Recent Australian studies (Sturgiss, 1995, 1996) note that primary production of metals is more energy-intensive than later stages, and thus exports at this level will necessarily be more energy-intensive. On the other hand, the relationship between energy and carbon intensity is still very much dependent on the fuel mix and technical efficiency in the primary production process.

Trade issues

In considering the competitiveness implications of an Annex I-wide carbon/energy tax, a key element is what proportion of traded goods, especially carbon-intensive goods, are located within the Annex I region. Clearly, the greater the percentage located within Annex I, the lower the probability that competitiveness *vis-à-vis* non-Annex I goods will be affected and thus the less leakage.

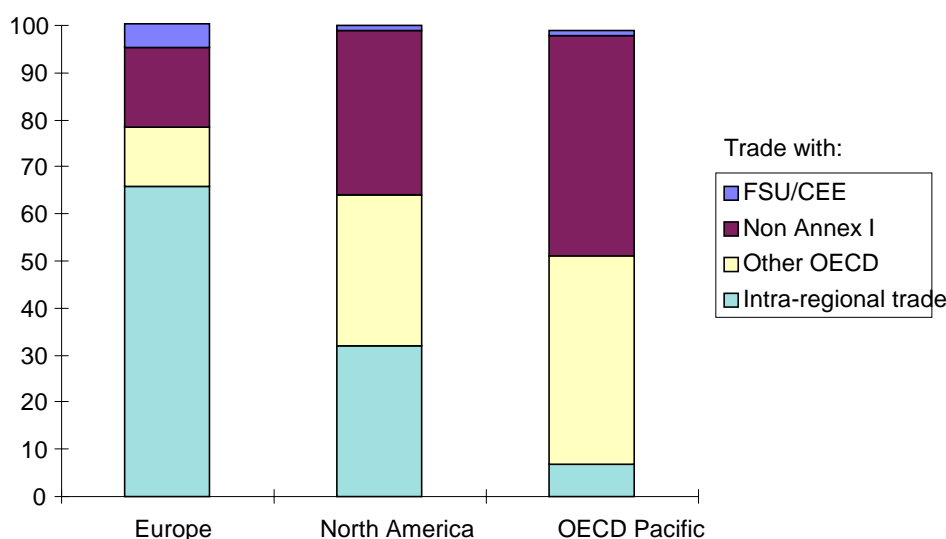
Figure 5 shows that more than 90 per cent of OECD Europe's aggregate exports and imports of goods are within Annex 1. However, both OECD North American Member countries, and especially OECD Pacific

¹⁹ In other words, economic efficiency does not necessarily imply low energy intensity.

Member countries export a larger fraction of their goods outside the group of Annex I countries. This obviously has to do with the proximity to important markets in developing countries. The degree of intra-OECD trade is quite similar, whether one looks at aggregate exports or imports.

At first glance, this primary data on trade implies that OECD European Member countries may be less exposed and that of OECD Pacific Member countries more exposed to distortions in competitiveness from a carbon/energy tax applied to the Annex I region. One needs to combine this data with the contribution of trade to GDP to obtain a better sense of the magnitude of the competitiveness issue (see Section 3).

Figure 5. Composition of trade in OECD regions as % of total trade¹⁾



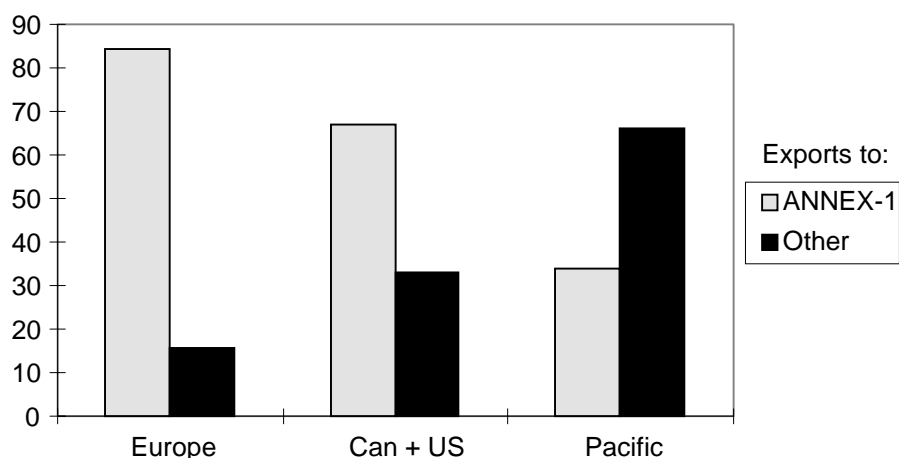
1) Average of exports and imports
Source: IEA/OECD, 1994 data

Figures 6 and 7 look at the ratio of OECD trade of energy-intensive products trade for both exports and imports. They suggest that the energy-intensive activities in OECD Pacific Member countries are more open to increased competitive pressure related to a carbon/energy tax than are the other two OECD regions. The OECD European region appears well buffered from changes in non-Annex I costs while North America is in-between.

In 1994, OECD's energy-intensive trade amounted to 18 per cent of exports and 15 per cent of imports. In all three OECD regions, exports of energy-intensive products outside OECD represent more than twice the imports of similar goods.²⁰ From 1970-1994, OECD regions have been net exporters of energy-intensive industrial goods.

²⁰ Trade in energy (as opposed to energy-intensive manufactured goods) gives rise to large bilateral trade imbalances. All three OECD regions have deficits in energy towards non-Annex I, reflecting mostly oil imports. Europe has a large trade deficit with the FSU/CEEC, mainly due to imports of natural gas.

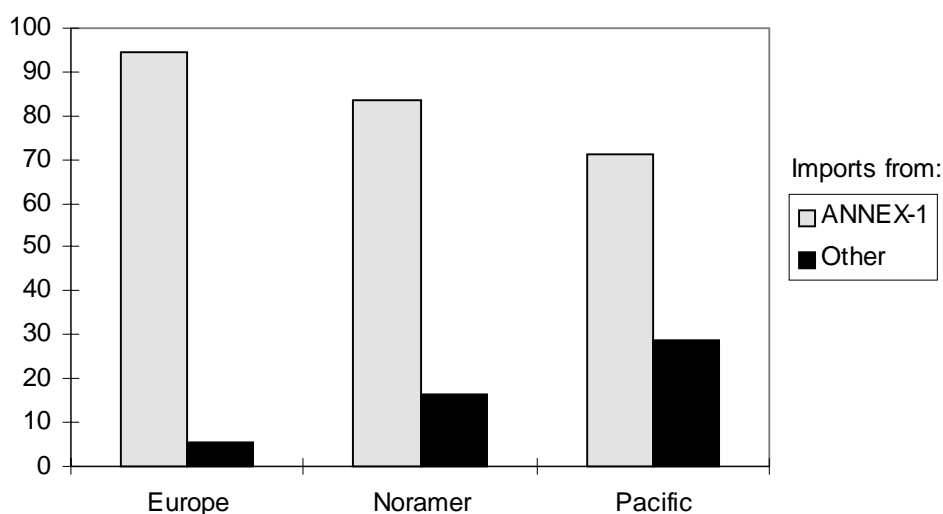
Figure 6. Destination of OECD's energy-intensive exports - Annex I and non-Annex I as a per cent of energy-intensive exports



1) Exports of chemical products (SITC5) paper and products (SITC64), iron and steel (SITC67) and non-ferrous metals (SITC68)

Source: IEA/OECD, 1994 data

Figure 7. Origin of OECD's energy-intensive imports - Annex I and non-Annex I as a per cent of energy-intensive imports



Note: See source and notes for Figure 6

In absolute terms, Europe has a significant trade surplus in energy-intensive goods, while North America and the OECD Pacific region has minor surpluses. All regions have net export surpluses in energy-intensive goods towards non-Annex I. Note that the situation of individual countries within these regions may be different from that observed at the aggregate regional level. Table 2 summarises the above information, including data on trade and GDP for the three OECD regions.

Table 2: Trade in energy-intensive products for major OECD regions (1994)

Region	OECD Europe	OECD North America	OECD Pacific
1. Exports of energy-intensive products* to non-Annex I over total exports	3.2%	4.9%	7.5%
2. Imports of energy-intensive products* from non-Annex I over total imports	1.0%	1.8%	3.7%
3. Share of exports (imports) of energy-intensive products* to (from) Annex I	80.7% (88.9%)	66.6% (79.1%)	33.3% (67.2%)
4. Net exports of energy-intensive products* to non-Annex I (Billion)	US\$ 39.8	US\$ 16.0	US\$ 21.3
5. Net exports of energy-intensive products* to other regions (Billion)	US\$ 53.0	US\$ 2.7	US\$ 8.0
6. Contribution of trade to GDP (Imports + Exports) / 2 * GDP	27.3 %	13.4 %	9.8 %

* "Energy-intensive products" are: iron and steel, non-ferrous metals, paper and pulp, and chemical products.

This section has provided orders of magnitude relevant in an assessment of the effects of carbon/energy taxation on competitiveness. Energy-intensive sectors, most likely to be exposed to increased competitiveness under increased energy prices, represent between 3 and 7 per cent of GDP, and 1 to 4 per cent of the labour force. These sectors represent net exports to non-Annex I for all three OECD regions, although the ratio of trade in energy-intensive goods with non-Annex I to total trade, a good yet static indicator of the magnitude of the issue, is in general small (see line 1. and 2. above).

Although the degree of exposure of energy-intensive industries to non-Annex I competition is highest in the OECD Pacific region and lowest in the OECD European region, the relative contribution of trade to GDP in Europe is about threefold that of the OECD Pacific region.

Effects of a carbon tax

We now turn to the question of the price increase that a tax on carbon would introduce on industries defined as energy-intensive.

This section of the paper looks at a hypothetical Annex-I-wide carbon tax of \$100 per tonne of carbon. This example is purely illustrative and is used to indicate the magnitude of effects on cost structures of major energy-intensive industries. Importantly, this example does not look at the design of any such carbon tax issues.

Experience shows that in real world conditions, the design of such a tax would clearly need to take into account how to: phase in such a tax so as to minimise competitiveness disruptions, recycle the tax revenues potentially to offset competitiveness effects, exempt certain sectors or industries for competitiveness reasons, and set the right level for the tax. All of these issues have complex interactions. For example, exempting any specific industry will presumably require higher taxes on other industries/sectors so as to achieve the same level of carbon reduction. For the sake of clarity, exemptions, recycling and other options for the compensation of potentially detrimental competitiveness effects are covered in Section 5.

The calculations are done as follows:

1. First, tax payments from use of all direct use of fossil fuels are calculated, taking differences in carbon content into account.
2. Furthermore, increased taxes through higher electricity prices as a consequence of taxation of fossil fuels in electricity generation are included. In this calculation, the fuel input structure of the national electricity generation sector is used. It is assumed that industry electricity prices rise in proportion to average costs in the electricity sector, which is more or less in accordance with existing pricing principles in Annex 1.
3. The final cost increases in absolute value is then divided by gross output, which is used as a proxy for per cent cost increases.

Table 3 summarises the different cost effects of a US\$100/tC tax across energy-intensive industries and countries. Chemical industry uses natural gas and other petroleum products as feedstocks in addition to normal energy use. Non-fuel use of energy (feedstock) implies that carbon is sequestered in the manufactured products. The table below first calculates the effects on cost if all fossil energy, including feedstocks, were to be taxed. In order to estimate the sensitivity to this assumption, the effects of a tax applied only to the energy use of fossil fuels are indicated in parentheses, for the chemical industry as well as total energy-intensive industry (Table 3).

The available energy data do not enable to fully incorporate process emissions of carbon. We have tried to account for the most important of these by making simplified assumptions about process emissions from aluminium production.²¹

Table 3. Selected OECD Member countries' cost increases¹⁾ from a tax of 100 USD/ton carbon as per cent of production value.

	Total energy-intensive industries	Iron and steel	Non-Ferrous metals	Chemical	Pulp and paper
USA	2.8 (2.5)	2.3	3.1	2.8 (2.2)	3.2
Canada	4.1 (3,3)	6.2	3.7	4.1 (2,3)	5.0
Japan	1.2 (1,0)	2.0	0.7	1.0 (0,6)	0.6
Australia	5.2 (5,0)	5.8	11.4	1.7 (1,4)	2.6
France	1.4 (1,1)	2.4	1.4	1.3 (0,8)	0.6
Germany	1.6 (1,4)	2.6	1.2	1.4 (1,1)	1.0
United Kingdom	1.6 (1,3)	3.6	1.9	1.2 (0,8)	1.2
Italy	1.4 (1,2)	2.0	1.1	1.3 (0,9)	0.7
Belgium	2.3 (2,1)	7.3	0.8	1.6 (1,2)	0.6

1)The figures also include carbon emissions through electricity generation and from process emissions in aluminium production.

Numbers in parentheses indicate cost increases when the tax is applied only to fossil fuels used for energy purposes, i.e. not-sequestered in the final product.

Source: OECD/IEA data, sectoral energy data: Energy Information Agency (1994), ECON calculations, see Appendix II.

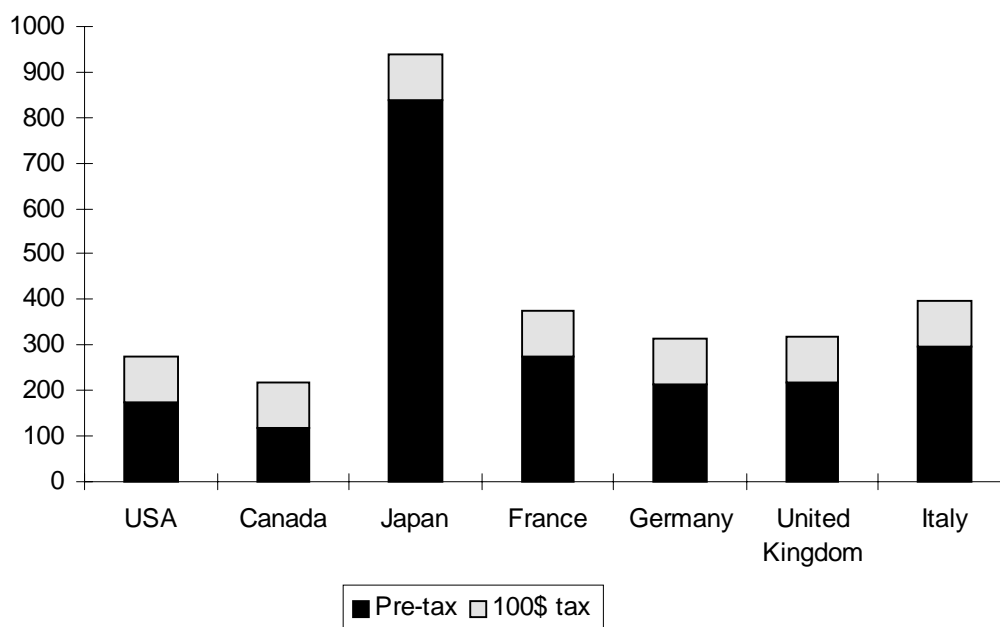
²¹ More details about feedstocks and process emissions are found provided in Appendix II.

Two observations are worth noting:

- except for Australia and Canada, the average cost increase (as defined as per cent of total production value) for energy-intensive industries is about 2 per cent or less,
- the ranking of the cost implications for countries is generally constant across the four industries sampled - i.e. countries with low carbon intensities tend to have small cost increases across all industries and vice-versa.

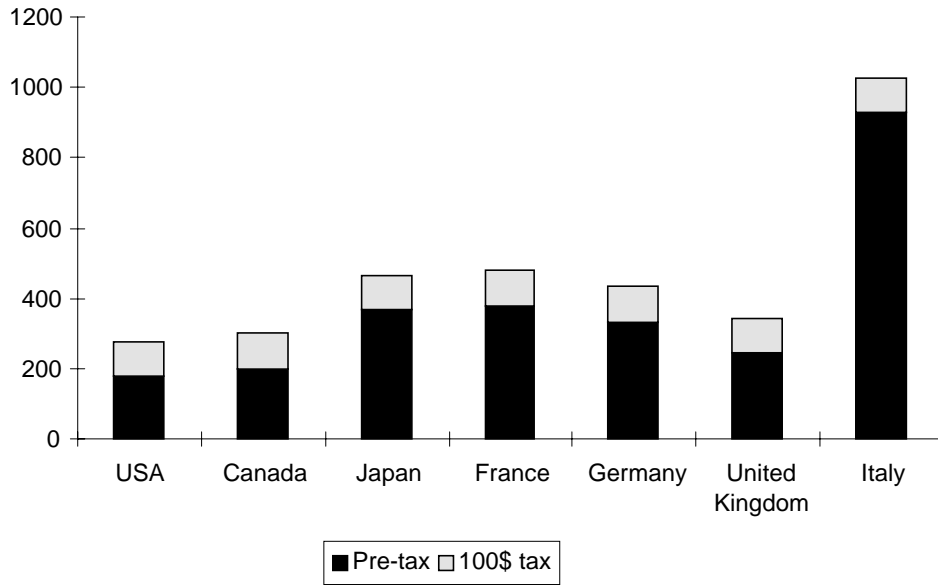
A central element of the above analysis is the existing pre-tax level of industrial energy prices across these countries. Here, starting points are widely different, reflecting different prices and different taxes. Although a uniform tax applied consistently to all fuels in all countries would not change the *ranking* of countries in terms of their relative energy prices, it would reduce the variance across countries. This is illustrated in the following three figures for gas, light fuel oil and coal.

Figure 8. Industrial gas prices with and without a carbon tax. USD per ton carbon



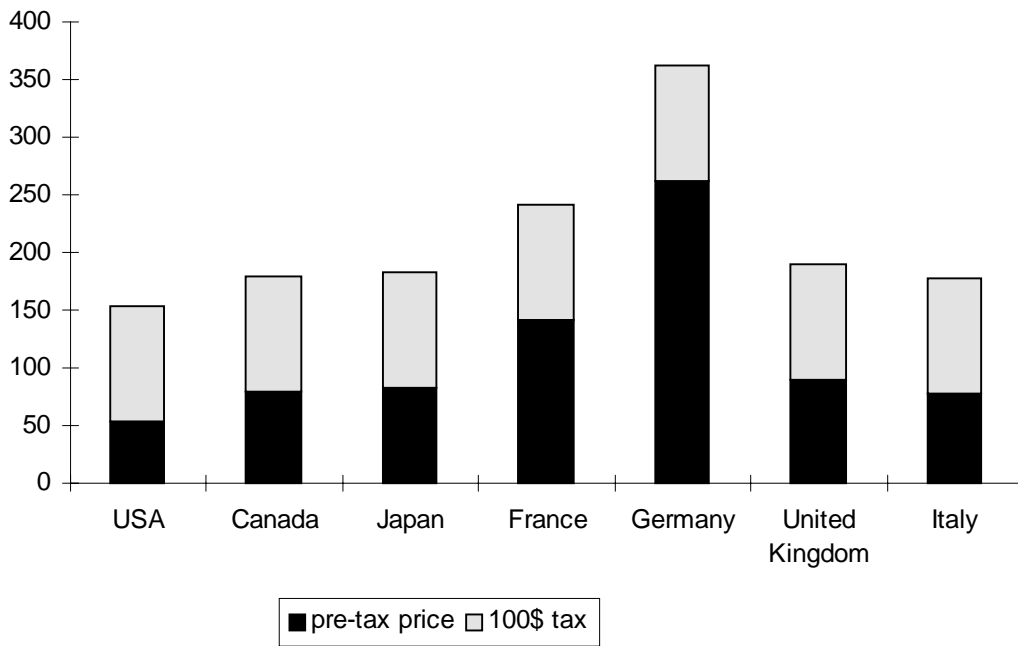
Source: IEA, 1995 data

Figure 9. Industrial light fuel oil prices with and without a carbon tax. USD per ton carbon



Source: IEA, 1995 data

Figure 10. Industrial coal prices with and without a carbon tax. USD per ton carbon

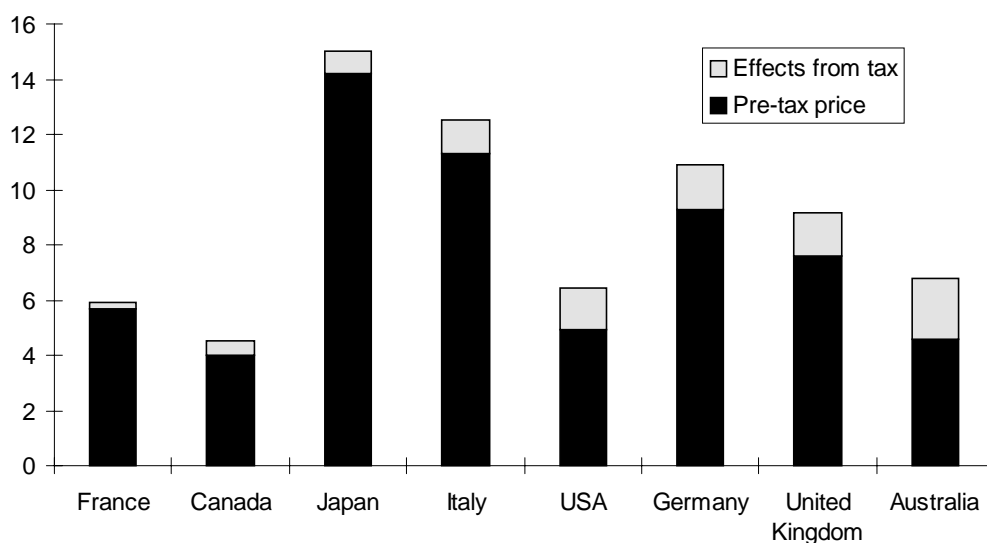


Source: IEA, 1995 data

Electricity prices, however, show both absolute and relative price changes. This variance is explained by differences the carbon intensity of electricity generation among countries²².

²² See Figure 4 in Baron *et al.*, (1996) for an illustration of this point.

Figure 11. Industrial electricity prices with and without a carbon tax. Cents per kWh



Source: IEA, 1995 data. It is assumed that there is a full pass-through of average electricity costs increase to end-use electricity prices.

The absolute increase in electricity prices will vary by a factor of more than 10. By far the lowest increase is for France, due to the large share of nuclear in electricity generation. Also, Canada has a low share of fossil fuels in electricity generation (23 per cent) and consequently a modest increase in electricity prices. Under the current regime of electricity sector regulation throughout most of the OECD Member countries, the increased costs would cause direct cost-plus increases in prices. In a more liberalised electricity market with larger scope for trade between countries, the consequences might be different with the competitive position of electricity enterprises influenced by the carbon intensity of their generating capacity.

The existing large differences in energy prices among countries²³ imply that the impacts of a tax on the competitive position will vary on a country by country basis. It is useful to mention two factors working in opposite directions:

- countries with higher relative energy prices tend to be less energy-intensive and may thus be less vulnerable to increases in energy costs (as well as the tax having a lower per centage impact on costs). This is illustrated in results shown in Table 3;
- energy-intensive industries in countries with higher relative energy prices have already made relatively large investments in energy-saving technologies, and thus further improvements will be more costly than for those with under-utilised, less costly options. This phenomenon is not reflected in the analysis of the static cost increase shown in Table 3.

It follows that industries which at the outset are more energy efficient may suffer relatively low profit losses in the short-term, while the costs of adjusting to the changes in energy prices could be higher in the medium term. Conversely, industries that are less energy-efficient due to low energy prices face a major

²³ See Baron *et al.*, (1996) Section 3, Figure 5 for an illustration.

increase in energy costs and loss of profit, but in the medium term, could have more opportunities to lower the energy costs through investments in energy-saving technologies.

Much more limited data exists for Annex I countries outside the OECD, but nevertheless, examining the available evidence on Russia and Poland (now an OECD member) indicates clearly that energy and carbon intensity of both the overall manufacturing and energy-intensive sectors are substantially higher than OECD averages. The reasons for this have been well discussed in other studies. Thus, a carbon/energy tax would have major cost implications within industry and would probably affect trade as well.

In the above section, we provide static, short-run estimates of what the effect of a US\$ 100/tC tax would be on product prices, i.e. what the effect of such a tax would be on the price competitiveness of these industries on international markets. Beyond the fact that this static analysis is fairly aggregate, and does not go into the specifics of sectors across countries, a few methodological points should be mentioned. These estimates are both pessimistic and optimistic:

1. On the positive side, from the standpoint of price competitiveness: first, companies would adapt to the new price regime, relying on potentially much more efficient processes that become economic when such a tax is introduced. Second, they may not pass all of the cost increase to consumers, or they may do so without affecting their market shares, if they act as price-makers.
2. On the negative side, these costs increases do not reflect the cascading effect of a carbon tax in the economy. Input-output analysis would provide a more accurate picture, still unsatisfactory for longer-run analysis, of the full price effects of the tax for these industries.

With these and previous caveats in mind, the main insight from the above analysis of the static price increases caused by a US\$ 100/tC for main energy-intensive industries is that they would be relatively small, with some industries in Canada and Australia being more affected than similar industries in the selected OECD Member countries. Additional insights are provided by the following overview of the past and current market situation for three energy-intensive industries.

The sample industries

This section looks at three specific energy-intensive industries on a static basis. In determining industry-specific trade effects of the illustrative carbon tax, four primary characteristics are important:

- the amount of the world market that is affected by the carbon tax;
- the size of transport costs between major regions;
- the degree of product specialisation, i.e. scope for market power;
- the possibilities for relocation of capacity outside the Annex I area.

For each industry, the recent trends in production and the location of new capacity are discussed so as to illustrate recent changes within the industry. The potential impacts of a \$100/tax on costs and trade are then noted. Table 4 displays the recent shares of world production of these industries.

Table 4. Shares of world production for selected carbon-intensive industries¹ (in %)

	Crude steel	Aluminium	Ferro-alloys	Nitr. Fertiliser
W. Europe	16	19	17	10
N. America	12	37	9	20
OECD Pacific	13	12	7	2
CEEC/CIS	35	12	14	24
Other	23	20	53	44

- 1) Source: UN(1994), 1992 data. Due to limited data availability, estimates for the CIS and CEEC have been made in some cases. The above goods are crude steel, unwrought aluminium, ferro-alloys exc. ferro-manganese and nitrogenous fertilisers.

The iron and steel industry

While OECD and CIS/CEEC have traditionally been the largest producers of steel, the steel industry has seen important structural changes since 1973. OECD production declined between 1973 and 1983, but increased again at an annual rate of 0.7 per cent between 1983 and 1992, reaching 41 per cent of the world total. Steel production in the countries with economies in transition plunged in the 1990s and has not recovered. Over this period, the strongest growth occurred in a few developing countries: China, South Korea, Brazil and India.

In the OECD area, employment in the steel industry has fallen by about 56 per cent between 1973 and 1993, with a 5 per cent decrease in the year 1992 alone. This decline can be attributed to the reduction in steel consumption, the increase in steel imports, and the modernisation through the use of labour-saving technologies.²⁴

Steel use is often closely associated with GDP growth (IEA, 1996), albeit there is also a long run tendency of replacing steel with other products in final demand (Nakicenovic, 1996). Steel consumption is also tied to the level and speed of economic development due to the effect of expanding infrastructure and increasing industrial demand. Thus, the high economic growth in some developing countries is an important factor behind the shift in the location of the world's steel industry. For example, British Steel (Matthews, 1997) notes that: "practically all new greenfield investment in integrated steel-making capacity in the last 20 years has been in developing (non-Annex I) countries."

While most of the world's steel production supplies domestic markets, steel is extensively traded internationally (Table 5). After 1989 however, when domestic consumption of steel in the CIS/CEEC collapsed, these countries increased their exports to the rest of the world.

²⁴ Kaesshaefer (1996).

Table 5. Net exports of steel (millions of tons)

Net exporters	Net exports	Net importers	Net imports
OECD Europe	32	China	40
Japan	19	East Asia	39
CIS	17	United States	14
Brazil	14	Middle East	8
Central and Eastern Europe	13	Africa excl. S. Africa	7
<i>Memo: World Steel production:</i>	<i>700</i>		

Source: IEA(1996) and UN(1994)

OECD European Member countries and Japan are large net exporters, while the United States is a net importer. OECD 'steel' imports are mostly related to steel embodied in manufactured products (such as cars, not accounted for as imports of steel) rather than raw steel itself.

According to the aggregate analysis presented above, a US\$ 100/tC tax would raise costs in OECD by 2 to 6 per cent. The scant evidence for the countries with economies in transition indicates much larger cost increases there. This variation reflects large technological differences and fuel mixes between these countries. Open hearth furnace, a less energy-efficient process than basic oxygen furnace, the most favoured method in large integrated steel plants, still represented 50 per cent of capacity in Russia and Ukraine, against a world average of 10 per cent.²⁵

Since there is no room here for a detailed market analysis, the following are probable factors determining the current competitiveness conditions on steel markets.

The present market share of the Annex I countries of what can reasonably be denoted a "world market" for steel is significant; probably a large amount of developing countries' steel production is directed towards domestic purposes and may also not compete against OECD Member countries' steel in quality. However, because of sluggish consumption in OECD Member countries and rising capacity in other countries, the steel industry in OECD Member countries has suffered from excess capacity for 20 years, with OECD Member countries' steel producers being the swing producers over the cycle.

Capacity utilisation is low in OECD and, due to the restructuring of their economies, very low in countries with economies in transition. On the other hand, in most developing countries, capacity has not been able to keep up with rapidly increasing demand, and little excess iron and steel capacity exists in these regions (only 1 per cent in China, 4 per cent in South Korea, to be compared with 23 per cent overcapacity in the OECD region in 1994). Lack of excess capacity outside Annex I implies the possibility of a pass-through of the tax on to steel prices.

The major competitors for Western European markets, namely, countries with economies in transition, would experience still higher cost increases than those reflected in Table 3. If the carbon tax results in a noticeable price rise for steel in the world market, one could not exclude the possibility of higher profit

²⁵ IEA (1996), Chapter 6.

margins in Western Europe, at least in the short run. Competition in direct steel trade from Asia/Pacific to either the United States or Europe, would be hampered by the high transportation costs involved.²⁶

Another feature of the steel market is the increasing differentiation of steel products, and the fact that not all producers are capable of producing the same products to the same standards.²⁷ Increasing quality specialisation could result in a higher level of trade, and may reduce the importance of price-competitiveness for some steel products.

Last, governments in steel-producing countries have adopted policies designed to promote steel exports, from export tax credits to infrastructure development, and steelmakers rely on trade laws to protect their domestic markets from low-priced or subsidised steel.²⁸ Thus, in many OECD Member countries, steel may be an industry which may seek compensatory measures to mitigate the cost impact of prospective carbon/energy taxes.

It is sometimes argued that moving steel production from energy-efficient mills in the OECD region to less efficient mills in developing countries would actually *increase* the world's carbon emissions (IEA, 1996), thus implying a high carbon leakage. This seems a rather worst case scenario and should not be considered very likely in a growing world market, although some leakage is to be expected. In a growing market, transferring steel production from Annex I to non-Annex I resulting from a carbon tax, would imply construction of new plants outside Annex I. Empirical evidence (Jaffe, 1995) indicates that multinational companies often use modern technologies irrespective of country location, implying that new plants will probably have an efficiency far above the average level in the host country. Smith (1995) also gives supportive anecdotal evidence. Still, low energy prices outside Annex I will influence energy choice, and probably imply a more carbon-intensive steel production in the new non-Annex I plants, than if such new capacity were to be installed within the OECD region. On the other hand, the potential for energy efficiency improvement is higher in developing countries and countries with economies in transition than in the OECD Member countries..

Production of aluminium

North America (mostly the United States) is the world's largest producer of aluminium. However, most of the growth in world output in the last decade took place in South America. With increasing hydroelectric production as a key advantage, Brazil tripled its production from 1983 to 1992 and now accounts for 6 per cent of the world's production of unwrought aluminium.

Asian production, outside Japan, has also increased rapidly, caused by a rapid increase in capacity in China and India. Australia is also a large producer that has displayed strong growth. Western European production changed little from 1983 to 1992.

Localisation of the industry has been heavily influenced by energy availability and costs. Aluminium is produced by electricity, with coal used in the electrolytic production process. Aluminium smelters are

²⁶ A study on the Dutch basic metal industry shows that transportation costs represent 10 to 17 per cent of total cost of steel slab imported from Australia, South Africa, and Turkey (p. 131, Gielen, Van Dril, 1997). On top of transportation costs, the EU and the US apply import levies to steel products, from 2.2 to 4.2 per cent for the EU and 0.7 to 8.1 per cent for the US, depending on the product type.

²⁷ Kaesshaefer (1996), Section 3.E on 'Outlook'.

²⁸ Kaesshaefer (1996).

usually located near the bauxite mines so as to minimise transportation costs, or increasingly near low cost electricity sources so as to minimise production costs. Thus, the competitiveness effect of a carbon tax on the siting of new plants is heavily dependent on the fuel mix in electricity production.

The analysis in this paper covers “non-ferrous metals”, which comprise other metals than aluminium, but the numbers should indicate the magnitude of the effects. Three groups of countries emerge from the cost analysis. Australia experiences the highest cost increases, more than 10 per cent, stemming to a large extent from high carbon intensity in electricity generation. North America is in an intermediate group, while Western Europe and most of all Japan would experience lower increases in costs in the short run. While diverse reasons are involved, energy and carbon intensity is clearly of high importance.

The OECD region’s share of world aluminium production is some 68 per cent, which indicates the market power to shift a significant portion of the price increase onto world market prices. However, profit margins would be very differently affected in different OECD regions. Australian producers would face high increases in cost, while West European and Japanese producers would have moderate cost increases.

EPRI (1994) undertook a detailed analysis of a carbon tax of the aluminium market, focusing on the United States. This detailed analysis considers cost effects for different process technologies. One conclusion is that cost increases are very diverse between plants. The analysis asserts that a US\$100/ton carbon tax would raise variable costs in many US plants using coal-based electricity to a level higher than total unit costs in new plants in South America, pointing to a possibility of a re-location of the US aluminium industry to Brazil and other countries. These results rely on the presumption that further expansion of electricity production in these non-Annex I countries is possible without raising costs. Their assessment is that Australian aluminium producers would still be in operation, but that capacity expansion would not be profitable as a consequence of the tax.

An important consideration of the effects on world aluminium production from a carbon tax seems to be the potential for expansion of low-priced electricity capacity outside the Annex I region. This is particularly relevant where significant energy resources have few or no alternative uses other than as an energy source for energy-intensive industry. Until now, hydroelectric power has been such an energy source in a number of countries. Some OECD Member countries that up until the present have expanded hydro production (e.g. Canada, Norway), appear to have utilised the bulk of their potential. Though frequently meeting resistance on environmental grounds in developing countries, the potential for cheap hydropower in a number of countries is probably still present.

In order to get a more precise picture of the effects of carbon taxation on aluminium production in different countries, the following elements would need to be incorporated:

- What type of aluminium products are traded? The share of energy costs in the overall cost of the final aluminium product (say, window panes) is much smaller than that of alumina, aluminium ingot and other semi-final products.²⁹ The more vertically-integrated companies are, the less reduced their profit margins would be, and the larger the potential for adjustments in cost structures.
- How fast secondary aluminium (from scrap) will be grow in the future? Indeed, secondary aluminium requires only about 5 per cent of the energy used for primary aluminium.³⁰

²⁹ Gielen and Van Dril (1997), page 57.

³⁰ Andrew (1996). Gielen and Van Dril (1997) find that for the Dutch aluminium industry, energy costs amount to 30 per cent of production costs for primary aluminium, whereas they only represent 3 per cent

While there are some constraints on the supply of scrapped aluminium, there is still room for further penetration of this technology, as its capital and energy costs are lower than for primary aluminium, and aluminium recycling is still on the increase. The availability of scrap (e.g. used beverage can) is a key determinant for the location of secondary aluminium production capacity, whereas cheap energy has been the main determinant of investment decisions over the past decade.

- How will aluminium compete with other metals (e.g. steel) in manufacturing activities such as car manufacturing under a constraint on CO₂ emissions? It is likely that aluminium would become more attractive as car manufacturers would search for ways to reduce the energy consumption of their products.

Lastly, the price increases for the aluminium sector must be compared to general market conditions for this commodity, where variations in stocks world-wide have led to very significant price increases between 1986 and 1988 (from US\$1 200 to US\$2 800 - 3 600 per tonne) and again during 1994 (from US\$1 000 to US\$2 000 per tonne).³¹

Production of chemical products

Chemical products consist partly of homogenous and highly tradable goods such as nitrogenous fertilisers, and partly of numerous specialised goods. The specialised chemical producers often have substantial market power, but the homogenous chemical producers are generally pure price takers.

Since 1983, the OECD region's share of world nitrogen fertiliser production has been around 32 per cent, with the CIS/CEEC producing an additional 23 per cent. According to Constant and Scheldrick (1992), production has mostly been located near natural gas resources, natural gas being used as feedstock in production. Canada, the Netherlands, Indonesia and particularly the CIS have previously undertaken large capacity investments. Countries in the Middle East with access to large quantities of gas with few alternative uses have also expanded fertiliser production. Transport costs are significant and help explain the rapid expansion of fertiliser production in many Asian countries with high growth in local demand.

The cost analysis of the entire chemical industry points to overall cost increases from a carbon tax of 1 - 2 per cent in most countries, with Canada being the highest with 4 per cent. In addition to technological differences, the composition of chemical production varies among countries. Still, the impression of cost increases for the chemical industry as a whole seems by and large modest. Yet, as surplus fertiliser capacity exists especially in OECD Member countries, the major producers within OECD and countries with economies in transition could experience loss of profits.

Main insights

This section indicates key orders of magnitude that determine the competitiveness effects, at the country/region level, of an illustrative US\$ 100/tC. Such analysis does not aim for comprehensiveness, as certain non-quantifiable factors, such as the level of integration of major companies, the types of products

of the production cost of secondary aluminium from scrap (p.68). They observe that secondary aluminium should be more profitable than primary aluminium in the Dutch context.

³¹ Andrew (1996), page 270.

traded internationally, the market position of OECD Member countries, as well as the margins for technological improvements, cannot be easily incorporated. Neither do we account for some of the real world features of carbon/energy taxation (levels applied to industry versus the rest of the economy, recycling schemes, etc.)

The manufacturing sector, and within this sector, energy-intensive activities, represents a variable share of OECD Member countries' gross domestic product. The contribution of trade to these countries' GDP is even more variable, generally decreasing with the size of the economy and the distance with trade partners.³² When looking at trade with developing countries, a primary concern if a tax were to be applied unilaterally by Annex I countries, is that energy-intensive products represent a net trade surplus; yet trade in energy-intensive products represents a small percentage of overall trade from and to OECD regions (more significant for the OECD Pacific region than for North America and Europe). Trade patterns in energy-intensive products for individual countries within the three OECD regions differ significantly from aggregate regional observations.

Energy-intensive industries (basic metals, chemicals, paper and pulp) would, in general, experience relatively small increases in production costs following the introduction of a US\$100 per ton carbon tax, with a few exceptions. Obviously, those countries/industries with lower energy prices and higher energy intensities would face higher price increases in the short run, as the tax would reduce the variance in industrial energy prices across OECD regions. Since our analysis relies on average observations at the sectoral level, the static price increases would be higher or lower depending on the company's profitability and the specific energy intensity of its output within the sector.³³

³² A good illustration of this point is provided by Figure 2, see the United States, Japan, Australia, Canada and Germany.

³³ See for instance, Hoerner and Muller (1996), Table 3, which shows sector-level totals for US industry similar to those shown above, albeit with significant sub-sectoral differences.

4. REVIEW OF EMPIRICAL AND MODEL-BASED ANALYSES

We now turn to more general analyses of the relationship between carbon/energy taxation, the broader domain of environmental regulation and trade. The above discussion has illustrated the complexity of these linkages. The following analyses have their own methodological shortcomings, they still provide useful, different insights especially on what might be the effects of an Annex I-only taxation of carbon/energy to abate CO₂ emissions.

Economic literature relevant to the issues of the impact of carbon/energy taxes and environmental regulation on competitiveness can be divided into two categories:

- the analysis of data to determine if, to date, environmental measures have had any appreciable effects on trade;
- the results of model exercises concerning the potential impacts of carbon/energy taxes on leakage.

In general, data analysis shows “*little evidence to support the hypothesis that environmental regulations have had a large adverse effect on competitiveness*” (Jaffe, 1995), albeit the data limitations and the difficulty of international comparisons limit the degree to which conclusions can be drawn. Concerning the empirical studies, it should be noted that a majority of environmental regulations to date have focused on command-and-control measures which are generally considered to be more rigid than taxation of environmental externalities. Thus, one could presume that the greater flexibility provided by economic instruments would allow industry to adapt its carbon-intensive processes in a more efficient fashion and thus reduce the impacts on competitiveness. Yet, OECD notes that: “*if fixed at an appropriate level, environmental taxes minimise the overall cost of achieving a given pollution control target, even though some firms or industries may face higher costs with ecotaxes than with regulations*” (1996.a, p.11). Indeed, a significant difference between command-and-control, grand-fathered emission permits and taxation for environmental regulation is that taxes apply a permanent cost on the remaining amount of externality, while the cost of complying with command-and-control, however high it may be, is spent once and for all.³⁴

Computable general equilibrium models show the existence of a wide range of potential leakage due to the implementation of unilateral carbon taxation, yet a review of critical assumptions shows that results should be considered with great caution, as the treatment of intra-industry trade, exchange rates adjustments and capital mobility, let alone technology, is often inappropriate. Macro-economic models based on econometric analysis generally find lower effects on competitiveness, or even negligible when carbon/energy tax revenues are recycled in the economy through a reduction of existing distortionary taxes.

³⁴ On the other hand, economic instruments are economically superior to command-and-control, in that they constantly spur the market to seek more efficient means to abate externalities, hence resulting in a lower cost for the economy as a whole.

Before turning to insights from empirical and model-based analyses, the next section offers an overview of how carbon-intensity has evolved in a selection of OECD Member countries over the past two decades.

Past trends in carbon intensity in the manufacturing sector

Greening *et al.* (1997) have done a detailed analysis of trends in carbon intensity in the manufacturing sector over the 1971-1991 period, a particularly rich one in terms of energy price changes, although the nature of those price changes prevents us from drawing conclusions on the effects of taxation on the manufacturing sector. Indeed, energy price changes (1973, 1979 and 1986) have been sudden in nature, whereas taxation would be announced and discussed in advance with the manufacturing sector, and they have been imposed from outside the region and only very partly recycled into the economies where revenues were generated (so-called *petro-dollars* did not systematically flow back into OECD Member countries). Secondly, their analysis only covers ten OECD Member countries (Denmark, Finland, France, Germany (West), Italy, Japan, Norway, Sweden, the United Kingdom and the United States), so their conclusions may not be valid outside that region.

Carbon intensity is defined as the ratio of CO₂ emissions per unit of value added from the manufacturing sector. The authors have decomposed trends in carbon intensity of the manufacturing sector into the following components:

1. changes in emissions from power generation;
2. changes in sectoral final fuel use;
3. changes in sub-sectoral energy intensity;
4. changes in sectoral activity share or structure.

Sectors include the five energy-intensive manufacturing sub-sectors (iron and steel, non-ferrous metals, pulp and paper, chemical industry; and stone, glass and clay), food and kindred products, and a seventh category for less energy-intensive sub-sectors. For the above countries and time period, the study shows that aggregate carbon intensities have declined for all countries (from 72.5 per cent for Sweden to 29 per cent for Denmark). Although declines for each country are explained by a combination of the above factors and different timing of changes:

“the primary cause of declines in aggregate carbon intensity appears to be a decrease in energy intensity, i.e. an increase in the average factor productivity of energy. However, other factors such as shifts in sectoral economic activity towards less energy-intensive industries and the use of lower carbon-emitting final energy types reinforce persistent, declining trends in energy intensity in some of the countries during the analysis period.” (Conclusions)

The authors also point out that increases in average factor productivity of energy were observed during periods of increasing or high energy prices, but also persisted after energy prices dropped in 1986 (which may be explained by the lead time of certain industrial investments). The switching from direct use of fossil fuel to electricity use (whether carbon based or not) has also resulted in reductions in energy and carbon intensities.

Another interesting result is that out of the ten countries, changes in the economic structure contributed significantly to reductions in carbon intensity for only three countries, where shifts away from heavy industry were important: the United States (33 per cent of total reductions), Japan (32 per cent), and West

Germany (18 per cent). For other countries, the contribution of changes in structure was either much lower or negative, i.e. changes in the structure of activities *per se* led to an increase in carbon intensity.

These results cannot be directly extrapolated to estimate the effects of carbon/energy taxation on the competitiveness of the manufacturing sector. Indeed, oil shocks represented both a very sizeable and very sudden price increase, with detrimental short-term effects on the activity of several economic activities. A realistic, politically acceptable carbon tax would not cause such a large increase in prices, would be clearly announced and would provide additional certainty about future energy prices, which would help companies optimise their investment decisions.

At the end, the experience of the two oil shocks still shows that the manufacturing sector has responded to price changes by adapting its processes and its cost structure, resulting in important reductions in carbon intensity.

Empirical analyses of environmental policies and trade

During the last decades, most OECD Member countries have substantially increased environmental regulation and thus the costs of environmental compliance. In recent years, the expenditures for pollution abatement and control for the major economies are often greater than one per cent of GDP. This level of environmental expenditures has often been cited as causing a “loss in competitiveness” for the affected industries. Testing this hypothesis is a difficult task, as there is little homogenous data on the cost of environmental regulation, nor a straightforward measure of the stringency of environmental regulations across countries. Yet several studies, reviewed by Jaffe (1995) and Adams (1997), have attempted to test this hypothesis. What follows is based on these two authors’ findings.

Using a model of international trade which assumes trade flows are determined by comparative advantage, Tobey (1993, in Adams) looked at the evolution of trade of industrial products generally considered as pollution-intensive (mining sector, primary metals, paper and pulp and chemicals), and concluded “*the important and consistent finding of the empirical tests was to show that the hypothesis that environmental regulations alter patterns of world trade is not supported empirically*” (p.50). Grossman and Krueger (1992, in Adams) examined whether pollution abatement costs influenced the patterns of bilateral trade and investment with Mexico: “*Mexican exports to the US are determined largely by the factor uses of the industries ... A variable reflecting pollution abatement costs in the US industry adds nothing to the explanation of the sectoral pattern of bilateral trade...*”

Recently Jaffe (1995) reviewed and analysed over one hundred studies that looked at the potential effects of environmental regulation on US competitiveness and concluded

“Overall, there is relatively little evidence to support the hypothesis that environmental regulations have had a large adverse effect on competitiveness, however that elusive term is defined. Although the long-run social costs of environmental regulation may be significant, including adverse effects on productivity, studies attempting to measure the effect of environmental regulation on net exports, overall trade flows, and plant location decisions have produced estimates that are either small, statistically insignificant or not robust to tests of model specification.”

Jaffe's rationale for this conclusion is based on the following:

- existing data is severely limited and the difficulty of measuring the stringency of environmental regulation makes it difficult to determine statistical significance between regressions on regulation and economic performance;³⁵
- except for the most heavily regulated industries the cost of compliance is not high enough to affect competitiveness;
- the stringency of regulation among the major “western industrial democracies” are roughly equivalent and do not alter trade patterns;
- in those cases where there are substantial differences between domestic regulatory regimes, multinational investors do not substantially alter the environmental performance of their investment;
- in countries with lower environmental regulation, investments by domestic companies are often built to higher environmental standards, thus mitigating the difference in statutory standards.

While recognising the data problems and the difficulty of cross country comparisons, it is worth noting that, of all the major published studies today, none has shown that environmental regulation has had a significant effect on competitiveness. Nevertheless this data is aggregate and could mask effects in specific firms/industries.

Model-based analyses

Two types of models have been used to examine the effects of a carbon/energy tax on the global economy: computable general equilibrium and neo-keynesian macroeconomic models. General equilibrium models used to analyse greenhouse gas policies have been primarily designed for analysing global, regional and national effects of abatement policies. Such models are global in the sense that they describe the behaviour of key sectors in different regions and integrate these regions via trade links. A common feature of these models is the assumption of full resource utilisation, and thus many transitional adjustments due to changes in terms of trade are not addressed.

In order to capture adjustment effects, traditional macroeconomic models have been used to analyse the effects of carbon/energy taxes on either individual countries or groups of countries. Often these macroeconomic models include a relatively detailed energy demand specification in order to describe factor substitution and energy effects throughout the economy. The models tend not to be sufficiently disaggregated to consider the effects on specific industries.

³⁵ In particular, Jaffe *et al.* write: “we could [ideally] measure the real effects of regulation on competitiveness by identifying the effect that the policy would have on net exports holding real wages and exchange rates constant”, yet no such studies have attempted to do so.

General equilibrium modelling of carbon abatement policies

Several world-wide general equilibrium models have been used to analyse the costs of carbon abatement, with the OECD GREEN model and the 12RT being two of the most noted. These models were compared (Manne and Oliveira-Martins, 1994) for a scenario aiming to stabilise Annex I emissions at their 1990-levels by 2010. In both models, the GDP losses as a consequence of abatement policies³⁶ are small (less than 1 per cent of GDP); however the amount of carbon leakage³⁷ is much larger in 12RT than in GREEN. In GREEN, leakage is less than 5 per cent in all years through 2050 (it is, in fact, negative early in the period) while leakage in 12RT rises from some 10 per cent in 2000 to 30 per cent or slightly above by 2040.

The most important reason for this variation is the different treatment of trade flows, especially in energy-intensive industrial goods. Manne and Oliveira-Martins estimate that almost two-thirds of the difference is explained by variations in specifications of trade behaviour. GREEN relies on a specification with a constant elasticity of substitution in import demand, which implies that despite higher costs in Annex I, the loss of market share is limited (though still significant). This specification best reproduces observed patterns of intra-industrial trade, and helps capture non-price elements of international competitiveness. In the 12RT model specification, a large fraction of tradable goods is viewed as homogenous, whereby a country, in principle, loses its entire sale in the world market if its export price exceeds that of its competitors' by only a small amount. Thus, changes in production costs imply a much larger loss of Annex I market shares than in GREEN.

In their recent study on competitiveness and taxation, Barker and Johnstone (1997) have reviewed several model-based analyses looking at carbon abatement policies in OECD and Annex I Member countries, and found that estimates of carbon leakage can vary from -45 to 80 per cent.³⁸ The bulk of the studies find leakage rates ranging from slightly negative to 35 per cent. Rutherford (1997) notes that: 1) leakage increases sharply with the carbon/energy tax and 2) the highest leakage occurs in models based on trade theory with homogenous products, undifferentiated by region of origin. The second point illustrates the importance of the elasticities of substitution between domestic and traded goods. On this question, Barker and Johnstone conclude that if one assumes that such elasticities are high, competitive losses and leakage will be estimated, but add further that "*Interestingly, the energy-intensive sectors are not particularly elastic*" and add: "*Those studies which draw on econometric evidence find that these elasticities are low and the competitiveness and leakage effects are small*" (section 4.3).

Two other important factors in the analysis of leakage are:

- the treatment of exchange rates: if exchange rates are assumed to adjust to new price levels, they will somewhat compensate losses in price competitiveness caused by the tax;
- capital mobility: if full capital mobility is assumed (e.g. to equalise rates of return across all activities world-wide, a common assumption in global computable general equilibrium models), the risks of relocation are completely obviated. In that respect, one should note that

³⁶ A carbon tax or tradable emission entitlements were analysed.

³⁷ As defined as increases in non-Annex I emissions in per cent of Annex I reductions.

³⁸ The latter figure is based on a model in which fossil energy is represented as a single good, preventing the reduction of energy-related emissions through fuel switching towards less carbon-intensive fuels.

so far, foreign direct investment from OECD Member countries goes mostly to other industrialised countries (Annex I).

When defining the long run as 15-20 years, the choice of how much general equilibrium features (full adjustment of supply and demand through price changes) and how much real world sluggishness (e.g. possibility of unemployment) to include in the model structure is open for discussion. Factors such as trade barriers, collusive behaviour and use of policy instruments such as subsidies may be important in determining the actual outcomes of a carbon/energy tax on trade.

Analysing carbon/energy taxes with macro-economic models

The other category of models used is macroeconomic models. Such models are less theory-based and more based on econometric analyses of aggregate data than General Equilibrium (GE) models. They often include more “real world” rigidities than GE models, such as unemployment, trade and government deficits, and inflation. Usually, macroeconomic models are more aggregated than GE models, and, in general, limited to describing the behaviour of a single country. In contrast, many GE models describe production and trade in the world economy.

For the most part, however, neither general equilibrium models nor macro-economic models used to study the effects of carbon/energy taxation have been designed to assess the competitiveness effects of carbon/energy taxation. To properly assess such effects, models should render both price and non-price elements of competitiveness, incorporate more sectoral detail, allow for structural and technical change, and be able to test hypotheses related to the strategic behaviour of firms inside and outside energy-intensive activities.³⁹

Macro-economic impacts: an overview

Unilateral carbon/energy taxes have been analyzed with macroeconomic models in several countries.⁴⁰ Preceding the debate of a common European Union carbon/energy tax, the Commission prepared several analyses of carbon/energy taxes. The results of the 1992 tax proposal (roughly a US\$10/barrel oil equivalent) were summarized in “European Economy” (1992a and 1992b). They were followed by updated analysis later. The results on GDP, employment and trade (competitiveness) can be summarized as follows. In as far as data are available, these studies show a reduction of CO₂ emissions of 4 to 9 per cent compared to a business-as-usual case. The older multi-country studies suggest losses in GDP of 1.2 to 1.6 per cent over a 5 - 10 year period, if tax revenues are not recycled and small reductions in employment (0.4 to 0.9 per cent).

These earlier studies also suggested that if taxes were recycled (to reduce personal income taxes, social security contributions or value added taxes), GDP losses would be lower (0.1 to 1.1 per cent) and impacts on employment might be less negative or even neutral, depending in especially on how these taxes were recycled. More recent studies suggest increases in GDP of 0.15 to 1 per cent and positive impacts on employment in case the tax revenues are used to reduce social security contributions paid by employers.⁴¹

³⁹ Barker and Johnstone (1997).

⁴⁰ For some further references, see e.g. Boero *et al.* (1991).

⁴¹ Bossier *et al.*, (1995) *Efficiencie energetique et nouvelles technologies*. Dans “Le progress technologique pour la competitivite et l’emploi.” Commission Europeenne., Joule II Programme, pp 87-111. Capros *et al.*, (1996) *Double Dividend Analysis; first results of a general equilibrium model (GEM-E3) linking the EU-12 countries*. In Carraro and Siniscalco (eds) *Environmental fiscal reform and employment*. Kluwer

Both older and more recent studies show that the current balance can be positively or negatively affected depending on whether possible export losses are compensated by decreased imports especially from energy.

Sectoral impacts

At the level of individual sectors, the impacts on production levels depend on the level of the tax, whether recycling takes place, on the country and the sector. Capros *et al.*, (1996) suggest losses of the energy-intensive sector of up to 1.5 per cent with recycling, for the 1992 tax proposal. Bossier *et al.*, (1995) report a loss of exports of 0.2 per cent for the intermediary sector compared to the baseline. These losses will be smaller, with recycling of revenues to reduce social security contribution paid by employers, since this type of recycling tends to increase GDP, boosting domestic demand, and compensating partially for any reduction in exports that may occur. Partial exemptions of energy-intensive industries, or ear-marked recycling of part of the tax revenues to these sectors in a way that does not affect the environmental objective, can further ease the burden on those sectors that are most negatively affected.

Academic Publishers , Dordrecht, pp. 193-227. CEC (1994) Besteuerung, beschaeftigung, und Umwelt: Steuerreform zur Abbau der arbeitslosigkeit. In: Jahreswirtschaftsbericht 1994; Europaische Kommission, Generaldirektion Wirtschaft und Finanzen, ss 111-144.

5. COMPENSATORY MEASURES

All carbon/energy taxes introduced to date in five European countries⁴² include some form of compensatory measures ranging from total exemptions for certain sectors, reduced rates for most energy-intensive processes, ceilings for total tax payments, subsidies for energy audits, etc.⁴³ Exemptions and other such features were introduced to accommodate competitiveness concerns of energy-intensive industries which argued that they would greatly suffer from similar industries operating in countries without such taxation. Exemptions have generally added to the administrative complexity of the taxation system, with provisions based on ratios of energy taxes to value added, which could be manipulated to obtain exemptions, e.g. in the early phases of the Danish and Swedish carbon tax systems. In other cases, certain activities were simply not covered, sometimes for reasons related to the risk of leakage, rather than that of pure competitiveness (long-distance fishing, aviation, etc.)

Among the energy-intensive sectors reviewed in this study, it appears that only a few would see a significant effect on their competitiveness. This implies that compensatory measures granted to these and similarly affected sectors could be limited in scope, while seeking to preserve the environmental goal, and avoid placing additional, inappropriate pressures on other parts of the economy.

In this section, we first consider straight exemptions of energy-intensive industries from an economic viewpoint, then turn to a discussion of other compensatory measures to see whether, if such measures are viewed as necessary, their negative effects (on the economy as a whole, on the environment) can be reduced.

Exemptions: an economic viewpoint

The principle of uniform taxation is to apply the same marginal cost to the use of a certain resource, so that the economy as a whole can mobilise the cheapest options to reduce emissions. Lowering the tax on certain sectors of the economy requires increasing this cost on other sectors, if the same environmental goal is to be met. In theory, this results in an increase in cost from the uniform taxation option.

In a context where other countries tax all activities equally, a country that would systematically exempt certain industries from a tax for competitiveness reasons would attract investment in such activities, leading to an increase in their emissions. In order to maintain emissions at some pre-agreed level, increasing taxation would have to be applied on the rest of the economy, which may be difficult politically.

The effects of exemptions on the cost of meeting a certain target and their influence on leakage of have rarely been estimated. Using the GREEN model, Oliveira-Martins *et al.*, (1992) have looked at the effects

⁴² Denmark, Finland, the Netherlands, Norway, Sweden.

⁴³ See Baron *et al.*, (1996), Section 3.2.2.3.

of a policy that would aim to exempt energy-intensive industries in the case of unilateral taxation within the European Community, while achieving the same level of reduction in CO₂ emissions.

They conclude, with appropriate methodological caveats, that the tax applied to the rest of the economy would have to be raised to offset unabated emissions from energy-intensive industries, and that, as a whole, these industries would undergo the same loss of output, caused by an additional reduction in GDP. They also find that the rate of emissions leakage would not be significantly affected. Hence, exemptions would neither benefit the environment through reduced emission leakage, nor the economy as a whole, nor those activities they aim to protect. While this is not definitive evidence on the effects of exemptions, it points towards their implications for the economy as a whole.

Beyond exemptions

In the debate over the interactions between environment and trade, a number of measures have been discussed to alleviate the negative competitiveness effects of environmental taxation, while minimising the negative effect from the standpoint of the environment. Hoerner and Muller (1996) propose criteria for evaluating such measures: effectiveness in protecting the competitiveness position of industries, the level of environmental incentive, the administrability of the measure, its fairness, and the revenue losses for the government (lower tax payments). While we cannot assess all measures against these criteria, they provide a useful objective framework for the assessment of compensatory measures.

Recycling

Taxation as an economic tool for reducing emissions offers the advantage to create revenues that can be recycled in the economy. Modelling results in Section 4 show that recycling tax revenues through lower payroll taxes can help reduce overall GDP costs and minimise competitiveness effects. Note, in particular, that since a carbon/energy tax would be raised on all energy uses (industries and households), but rebated entirely to the productive sector through lower payroll taxes, this sector would record a net reduction in its overall tax burden. While this paper deals primarily with energy-intensive activities, i.e. whose energy costs are generally higher than labour costs, the competitiveness of more labour-intensive sectors would actually improve through lower labour taxes. Similar modelling results exist for the United States, where investment tax credits appear to be the best option from a macro-economic standpoint.⁴⁴

Another means of recycling tax revenues to minimise the cost impacts of most energy-intensive industries is to offer tax credits for investments in more energy efficient processes. This would require establishing a set of criteria to determine which investments are eligible for such credits. Danish experience shows that this necessitates some trial and error, as these criteria can be manipulated by applicants, but that such systems are feasible and useful over a transitional period (Hoerner and Muller, 1996).

Conditional exemptions, ceilings, and adjusted rates

Governments have provided creative ways to help reduce the negative economic effects of carbon taxes, while trying to preserve their role as an incentive for lower emissions. An illustration of this point is offered by Switzerland, in its law on CO₂ emissions currently in discussion: a CO₂ tax would be introduced by the government if other measures have failed to set the country on track for its 2010 target.

⁴⁴ See also Baron *et al.*, (1996), Section 4.1.2. for more details.

Certain companies would still be eligible for exemption, provided they sign a legally-binding agreement with the government to achieve a certain emission target. If the company/sector does not meet its previously agreed target, the exemption is cancelled and the CO₂ tax has to be paid for emissions that have taken place over the period, *with interest*.⁴⁵ Such a mechanism would provide a strong incentive for reaching the agreed target. Denmark also offers reduced rates to the productive sector conditional on meeting energy efficiency goals in the context of voluntary agreements.

A common measure to offset the cost on certain industries is to apply a ceiling on total carbon/energy tax payments. The issue here is whether such ceilings still preserve the incentive to reduce emissions: if the ceiling is set too low, certain industries may not be able to decrease their emissions enough to be able to reduce their carbon/energy tax burden, and would lose interest in CO₂ abatement options.

Another option is to introduce a set of tax rates (decreasing as tax payments increase) so as to reduce the average cost for large emitters, while providing a permanent incentive for reducing emissions. Such a system was proposed by the Swiss government in 1994, but never implemented.⁴⁶ It consists in a tax rebate system applied to industries in energy-intensive sectors,⁴⁷ and which can prove that their energy costs (for the part of energy that would be subject to the tax) represent at least 3 per cent of their gross output. From that level on, increasing tax rebates are applied to activities depending on their energy intensity (between 3 and 4, 4 and 5, etc.) The rates are so designed that a company whose intensity is between 3 and 10 per cent has a permanent incentive to reduce its energy intensity to lower its overall tax burden. This is an example of a targeted tax system which, if applied, would have maintained an economic incentive to abate emissions.

Border tax adjustments

It is often suggested that competitiveness problems from carbon/energy taxation can be minimised through border tax adjustments (BTA), i.e. the remission of taxes on exported products and the imposition of taxes on imported products; BTA are intended to ensure that internal taxes on products are trade neutral (OECD, 1997). There is no agreement as to whether border tax adjustments could be used to offset carbon/energy taxes. Stewardson (1994), Hoerner and Muller (1996) argue that BTA on embodied carbon/energy would be allowed GATT rules, even though no attempt has been made to introduce BTA for carbon/energy taxation so far. In fact, no trade measure based on production and process methods (the case here) have ever been applied in the context of transboundary pollution. The practicality and the legal requirement of such measure is under discussion and study by the OECD and the WTO.

Stewardson mentions a practical difficulty in assessing how much of a tax on inputs has effectively been passed through to the price of a particular final product, which is the basis for the tax adjustment on exports. The possibility of over-estimating the adjustment would pave the way for disagreements and trade disputes. There is also a risk, if non-homogenous BTA and tax systems are applied among trade partners, for products to be taxed either twice or not at all, depending on the principles on which countries

⁴⁵ *Message relatif à la loi fédérale sur la réduction des émissions de CO₂*. Chapitre 232, p.42. For payment in case of non-compliance, see Article 9, paragraph 6, p. 62.

⁴⁶ Département Fédéral de l'Intérieur: *Taxe CO₂ prélevée sur les agents énergétiques fossiles - Rapport explicatif*. 23 mars 1994. Ch. 25.

⁴⁷ That way, companies with high energy consumption in sectors which are not categorised as energy-intensive would not be eligible.

have based their BTA.⁴⁸ In other words, significant international co-ordination would be necessary for BTA systems to effectively reduce the potential competitiveness effects of carbon/energy taxation and maintain the environmental goal. The benefit of setting such mechanisms ought to be measured against:

- their cost to the administration;
- the number of sectors/activities which would require such adjustments;⁴⁹
- the availability of other measures, described above, to offset price competitiveness effects of carbon/energy taxation;
- their transitional nature, given the prospect of greenhouse gas policies being adopted by all Parties in the future.

⁴⁸ “One could apply a destination principle, rebating on exports and imposing full taxes on imports, or [...] an origin principle, neither rebating on exports nor imposing charges on imports, or [...] a default destination principle, not rebating taxes on exports but allowing for taxes paid abroad in assessing taxes on imports” (Stewardson, 1994, p. 105) “Widespread adoption of the default destination principle in respect of imports of final products, and the destination principle with respect to the import of energy products, would contribute to avoid [trade] disputes. With respect to exports to countries not applying a carbon/energy tax, the origin principle would avoid the problem of no taxation, but would leave the competitiveness problem open.” (ibid, p. 106).

⁴⁹ Hoerner and Muller argue that BTA need only be applied to a few industries and a small number of products.

6. CARBON/ENERGY TAXES IN THE CONTEXT OF INTERNATIONAL TRADE

The focus of this paper was to cover competitiveness issues related to the taxation of carbon/energy to abate energy-related greenhouse gas emissions in Annex I, and, more specifically, to look at the effects of such policy on energy-intensive activities, whose cost structures would be most affected by increases in energy costs. After a discussion of competitiveness in the context of carbon/energy taxation, the following elements have been covered:

- What are the orders of magnitude to be considered when looking at this issue, in terms of Annex I or OECD Member countries' gross domestic product, employment, overall trade?
- What are the orders of magnitude of price increases for different energy-intensive industries, based on an illustrative carbon tax of US\$ 100 /tC?
- What is the general market situation of sample energy-intensive industries?
- What can we learn from empirical and model-based analyses of the links between environmental regulation and trade?
- What would be possible mechanisms to offset negative competitiveness effects?

The cost analysis, along with other empirical results suggest that competitiveness effects may be limited to a few activities in certain countries, whereas other activities may experience gains in price competitiveness through the recycling of the tax (e.g. through a reduction of taxes on labour). The study did not look at these potential benefits in great detail.

Furthermore, a carbon/energy tax would only be one among many and varied influences on trade. Here, it is useful to quote from the OECD report on industrial competitiveness (1996⁵⁰), which highlights priorities for competitiveness policies in OECD Member countries: minimising costs; increasing productivity; facilitating market openings; and strengthening infrastructures. Under minimising factor costs (labour, capital, machinery, intermediary goods, energy, government services, infrastructure, etc.) three headings are identified:

- “Regulatory reforms adjust economic regulations which have an impact on labour, capital, and other input costs”;
- “Tax wedges which create gaps between factor costs and factor incomes are to be minimised”; the report mentions two key areas in that respect: non-wage labour costs and taxation of industrial capital in capital markets, and adds: “the feasibility and sustainability of these reforms will depend on the success of governments in reducing total budgetary expenditures and in finding alternative sources of taxation”;

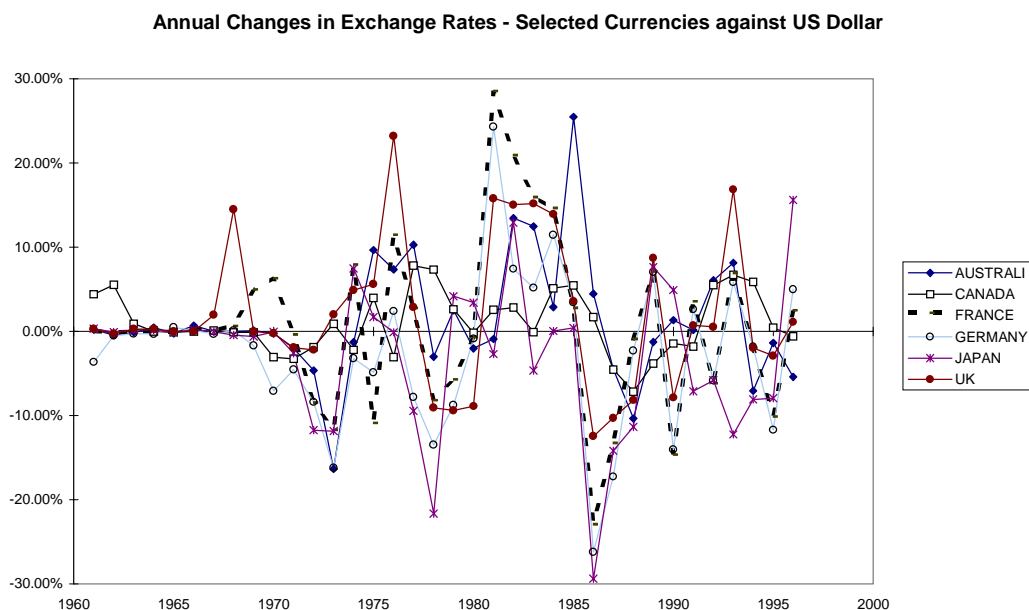
⁵⁰ See section 2: The priorities, p. 17 and after.

- “Exchange rate policies intervene in the formation of production costs”; several factors which are not related to basic cost fundamentals influence currency rates and may perturb the price competitiveness of business sectors. Governments should aim for more stability and soundness of exchange rates.

The two first bullets suggest that while the tax burden on *all* factors should be kept to a minimum, it is important to find new sources of taxation to reduce tax wedges on primary factors, labour and capital. Put in the context of this paper, the trade-off appears to be between *overall* price competitiveness and the price competitiveness of energy-intensive industries, as carbon/energy taxation can be a source of new taxation to reduce the above-mentioned tax wedges. If energy-intensive industries were to be exempted, the issue of their emissions would need to be addressed through other, potentially less efficient, policy measures.

With respect to exchange rates, a discussion of monetary policies in OECD Member countries is beyond the scope of this paper, yet it draws our attention to what is generally viewed as a primary factor in international competitiveness. Andrew identifies “becoming a metal producer in a mix of currency areas to reduce exposure to currency volatility” as one of the goals of the ongoing restructuring of the aluminium industry (1996, p. 275). Indeed, Figure 12 shows wide annual variations in exchange rates over the past three decades, sometimes as large as 30 per cent. Such variations have large effects on the price competitiveness of internationally traded goods, and should be compared with the indicative cost increases estimated in Section 3.

Figure 12. Illustration of exchange rates variations for selected OECD Member countries



Source: IEA database

In its discussion on increasing productivity (“the bridge between domestic factor cost and the price competitiveness of firms”) the OECD report notes the technical (input/output) and adaptive (output structure) dimensions of productivity. The former is “the ability to conform to (and to shape) the technical frontier in production processes”; the latter is “the flexibility of firms in re-directing their resources and outputs to high value-added market segments”, a matter of technical capability and the

ability to change the organisational structure of firms to serve less contested market segments. In the past, the manufacturing sector of OECD Member countries' economies has shown its ability to adapt to new economic conditions, sometimes through drastic changes in industrial structures (e.g. the closure of most of Japan's aluminium capacity in the early eighties⁵¹), but also through an improvement of its energy efficiency in response to the two oil shocks. Technological changes, e.g. in the iron and steel and aluminium industries, are still contributing to further improvements in the energy intensity of these activities. If clearly announced and phased-in, the disruptive effects of carbon-energy taxation on energy-intensive industries could be reduced.

The traditional economic theory on trade patterns is the Heckscher-Ohlin model, where trade is a function of technology, factor supplies, and government policy (Learner, 1995). Indeed, the driving forces behind trade in the last few decades are generally considered to be: 1) government policy encouraging trade (e.g. relaxing of trade barriers, the European Union, GATT) and 2) the increasing impact of technology. Despite these changes, the two major determinants of trade are still location - the closer the countries, the greater the trade - and the absolute size of the economy - the larger the economy, the lower the contribution of trade in GDP (Krugman, 1995).

Changes in competitiveness are often increasingly tied to technological change and to the utilisation of low cost labour. The technological change argument is that, while technology itself is quickly transferred between countries and therefore not a source of long-term comparative advantage, "*institutions that generate new technology on an ongoing basis and train complementary technical labour are likely to be the main source of long-term technical comparative advantage for high technology industry.*" (Dollar, 1995) Dollar goes on to note that a country's ability to develop such a comparative advantage in technology (or for many other industries) is dependent on the size of the domestic market, its openness to trade and investment, its educational system, the size and role of government, and capital accumulation.

Industrial migration related to lower-cost labour is one source of much concern in the traditional industrialised countries. While such a subject is far too broad for this paper, such migration has been significantly impacted by the ability to divide the value chain of production (the various components of a product), such that relatively low-cost labour can be used to produce the most labour intensive components. However, the difference in labour costs is usually measured in two-digit magnitudes, where the cost impact of a carbon/energy tax, even in the most affected industries, is in the 10 per cent range.

Therefore, in trying to measure the potential economic effects of a carbon/energy tax, care must be taken to both evaluate its significance within the other factors that influence international trade, as well as other priorities in competitiveness policies, and to realise that the likely *economic* effects of such a tax will probably diminish over time.

⁵¹ See Andrew (1996).

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APPENDIX I. EXECUTIVE SUMMARY FROM TAXATION STUDY⁵²

Economic/fiscal instruments: “Taxation (i.e. carbon/energy)”⁵³

The objective of this study on *Taxation (carbon/energy)* is to analyse the feasibility of applying such taxation at a common level within Annex I countries drawing from existing experience with taxes implemented to reduce energy-related CO₂ emissions, as well as from a range of available modelling and policy studies.

Context

In most OECD Member countries, almost all forms of energy are taxed to varying degrees, not primarily for greenhouse gas purposes, but to raise government revenues or to internalise other externalities. In fact, there is often an almost inverse relationship between fossil energy price levels, including taxes and subsidies, and their carbon content, i.e., fossil fuels with higher carbon content have lower end-use prices than those with lower carbon content. On a sectoral basis, industrial energy use is generally subject to a low level of taxation, whereas transportation fuels are usually heavily taxed, although with some disparity across countries. There is currently little commonality in the level of final-energy pricing, nor is there any commonality in the energy resources and fuel mixes among Annex I Parties.

Five countries (Denmark, Finland, the Netherlands, Norway and Sweden) have adopted carbon/energy taxes which generally include some rebates or exemptions for industry on competitiveness grounds, or alternative measures to achieve similar objectives. At least two other countries have considered modest carbon/energy taxes (Australia and the United States), but those proposals were not accepted. New Zealand has decided that a carbon tax will be introduced in 1997 if emissions are not on track to achieve existing targets, but is also examining alternative approaches, such as tradeable permits.

The European Union is in the process of considering a proposal for a common carbon/energy tax put forward by the European Commission.

52. Annex I Expert Group on the UNFCCC Policies and Measures for Common Action. Working Paper 4: “Economic/Fiscal Instruments: Taxation (i.e. Carbon/Energy)” (OECD/GD(97)188

⁵³ The full study can be downloaded from the OECD Climate Change website at: <http://www.oecd.org/env/cc/cc2.htm>

Policy objectives

The principal policy objective of taxing carbon and/or energy is to provide incentives to reduce CO₂ emissions, whether through fuel switching, energy conservation, or modal shifts, especially in a context of relatively low energy prices.

Taxes on carbon/energy also help reduce other environmental externalities. Studies for specific countries indicate that the secondary benefits achieved through reductions in other environmental impacts could offset part of the social cost of taxes, as estimated in these studies. In some cases, however, countries have already taken independent steps to abate other environmental impacts, therefore secondary benefits may not always be significant.

Revenues from carbon/energy taxation can be used to reduce other taxes that are viewed as introducing high distortions on the economy, and help achieve other policy objectives.

Approach and methodology

This study relies on modelling literature (IPCC Working Group III and other specific studies, when appropriate), as well as on current carbon and/or energy taxation policies that have been introduced to limit CO₂ emissions, including implementation issues, recycling schemes and differentiated sectoral approaches. When possible, lessons are also drawn from pending or rejected proposals for carbon/energy taxation.

A key methodological problem arises from the difference between taxes that have been implemented and modelling approaches to carbon/energy taxation, in particular when looking at common taxation across countries or regions. Implemented taxes are introduced as part of policy packages to reduce energy-related CO₂ emissions. These take into account sectoral differences, through differentiated tax levels, exemptions, or subsidies for energy efficiency improvements. Most modelling studies, however, look at a single-level tax as the only instrument to abate emissions.

In studies based on global economic models, the tax should be considered a proxy for the marginal cost of reduction. As such, these studies often provide results that apply to all greenhouse gas reduction strategies: some of their results are not specific to taxation as a tool to reduce emissions. In theory, any difference in marginal costs of reduction across regions entails that similar reductions can be achieved in a more economically efficient fashion by equalising the marginal cost of reduction, represented by a common tax. It is not at all clear that cost and greenhouse gas potential estimates from such studies can be used to compare unilateral and common actions, given the complexity of real taxation schemes, as illustrated by current experience.

Furthermore, studies of unilateral taxation fail to describe what actions are taken by other Annex I Parties to limit their emissions. This and the previous points lead to the conclusion that it is not possible to provide a fully quantified comparison of unilateral versus common taxation.

Last, but not least, this study does not address issues related to equity, a potentially key element in the design of and agreement on common carbon/energy taxation.

Description of measure(s)

The study looks at taxes based on the carbon and/or energy content of different fuels, from carbon taxes to energy taxes. As an illustration, restructuring *existing* energy taxes applied to all fossil fuels, based on their carbon/energy content would contribute significant CO₂ reductions. This, however, is not a straightforward option, since existing taxes have been introduced for (fiscal, environmental and other) purposes that cannot be discarded.

The schemes adopted for recycling tax revenues are crucial for the analysis of the economic impacts of carbon/energy taxes. Among others, the study looks at the opportunity of using tax revenues to finance carbon/energy efficiency improvements in sectors where the increase in energy expenditures would be most damaging, e.g. due to rigidities in the capital stock. It also touches on the possibility of coupling carbon taxation with carbon sequestration.

Different national circumstances, e.g. with respect to the level of economic development, the availability of energy resources and end-use energy prices, are potential barriers to implementation of a single carbon/energy tax as a measure for common action at the moment. A less ambitious suggestion would be to agree on pricing as an instrument to reduce energy-related CO₂ emissions in the long run, such as an agreement to keep domestic fossil fuel/energy prices from declining in real terms. However, further analysis would be needed to look at implementation issues related to such an option.

Rationale for common action

The rationale for common action is based on theoretical and empirical analyses which find that a more cost-effective outcome in aggregate economic terms would be obtained if all participating countries would equalise their marginal cost of reduction, represented by a tax in modelling studies.

An agreement to introduce price signals on carbon/energy would make such policy more effective than if it were adopted unilaterally. It may also help avoid establishing complex border tax adjustments between participating countries, although border tax adjustments might still have to be implemented for trade with other regions (pending their being legally and technically feasible).

A widely-agreed price signal on CO₂ emissions could create a significant market for lower-carbon technologies. This could result in cost reductions for such technologies, through economies of scale enabled by sales on a larger market than in the case of unilateral action, without picking “winners and losers”.

In practice, a number of implementation issues stand in the way of adopting a common taxation, starting with sectoral differences within countries, and different levels in energy pricing (see the experience of the carbon/energy tax proposed by the European Commission). When common taxation is considered, a flexible approach, e.g. relying on phased-in price increases, or a broad agreement on the need to reflect the cost of climate change in energy prices, may alleviate some implementation problems at the national level (e.g., the need for exemptions on competitiveness grounds).

Possible participants and vehicles for action

The question of possible adoption of carbon/energy taxes either at national or some common level among Annex I Parties must be addressed on the background of current energy policies. Countries with

economies in transition are still trying to reduce subsidies and achieve pricing at marginal production cost for all end-use sectors. Raising prices to cover production costs should already contribute to reducing energy-related CO₂ emissions. Real carbon/energy taxes, to be applied on top of the marginal cost of production, are not likely to be a priority for those countries before marginal cost pricing is achieved, i.e., subsidies are removed.

Greenhouse gas reduction potential

General modelling results

Modelling studies typically evaluate the impact of reaching different limitation and reduction objectives through the use of carbon and/or energy taxation. These target-based studies suggest that the potential for abating CO₂ emissions from energy use through carbon/energy taxation is, in general, high, in the long term. Modelling results confirm the economic intuition that CO₂ emission reductions are obtained more effectively with carbon taxation than with carbon/energy or energy taxation. These results are produced under specific assumptions, such as optimising behaviour by all agents in the economy.

Price instruments, if applied coherently over the long-run, do provide a signal to abate the energy intensity of production and consumption. It can be said that current modelling approaches tend to underestimate the adaptive behaviour of producers and consumers over the long run in response to steady changes in price signals, because global economic models underestimate the technology innovative responses, and phenomena such as economies of scale and learning curves, which could increase the reduction potential of a given tax level.

Economic and technology-based models both indicate that the marginal reduction cost to achieve a similar reduction objective would vary across countries, a conclusion that is consistent with different national circumstances. Because of differences in marginal cost of reduction, global economic models arrive at the conclusion that equalising marginal reduction costs, e.g. through a common tax level, would minimise the aggregate GDP cost, or that a higher reduction potential could be achieved at the same overall GDP cost. Again, this conclusion illustrates a general economic principle that applies to all policies and measures able to equalise marginal reduction costs across all greenhouse gases and sectors.

Results for the short and medium term indicate that energy users would respond to a price signal over time by reducing emissions, although simple utility and production functions do not adequately render the existing rigidities of certain demand categories, or the lead time necessary for adjustment. Energy use in transportation, already highly taxed for fiscal reasons in most Annex I countries, would not respond significantly without the introduction of new technologies and changes in infrastructure, since alternative means of delivering mobility or fuelling most transport modes are not readily available. This suggests the need for progressive introduction of taxes, instead of a strong signal at the outset.

In general, given shortcomings inherent in model-based analyses, results included in this study are mainly indicative of some of the effects of carbon/energy taxes on the overall economy.

Carbon leakage

Carbon leakage takes place when reduction strategies pursued in one region entail an increase in emissions in another region. The IPCC Second Assessment Report suggests that estimates of leakage

range from negligible to almost 100 per cent, for some specific activities. Carbon leakages can take place through two channels: the loss of comparative advantage from adopting a tax, resulting in increased production of energy-intensive goods elsewhere, and the effect of lower demand for fossil fuels on world energy markets.

As for the effects on comparative advantage, if there were a common action to introduce price signals, there would be less opportunity to re-locate production in a country with similar levels of economic development. For countries trading mostly outside Annex I, however, emission reductions achieved at home may be offset by an increase in emissions outside the region. Although energy expenditures amount to a relatively low percentage of GDP within OECD economies (between three and 11 per cent on a purchasing power parity basis, with a 5.8 per cent average for the OECD area as a whole), energy-intensive industries would still lose competitiveness, all other things being equal, if other trade partners were not to adopt similar carbon/energy taxes.

With regards to energy markets, it can be argued that common action to reduce energy-related emissions within Annex I, if not achieved through absorption or carbon removal, will entail a decrease in global energy demand, lower international prices and spur emissions outside the region. However, this effect is not specific to a tax. A similar drop in energy price will occur whatever policies and measures are used to obtain similar energy-related CO₂ reductions, insofar as they reduce the demand for tradable fossil-fuel based energy.

Economic effects (costs and benefits)

For the most part, economic effects of carbon/energy taxation are derived from macro-economic modelling approaches. As mentioned in the section on “approach and methodology”, a number of limitations apply to such modelling results. Among others, these models can only confirm the theoretical economic superiority of a single price signal to achieve an overall reduction objective within a group of countries, compared with unilateral taxation policies to achieve such reductions on a country-by-country basis. In that respect, this study does not shed any new light on the economic benefits of using a common price signal.

Short-term economic impacts are assessed with so-called macro-econometric models, which account for unemployment and other market disequilibria. Longer-run economic impacts are generally estimated with computable general equilibrium models, assuming that all markets operate efficiently. These economic models, *in general*, do not account for sectoral differences, especially with respect to the degree of elasticity in response to price signals over different time frames.

Another shortcoming of most macro-economic analyses is that they do not take into account a “no-regrets” potential and existing market barriers to energy efficiency improvements. A tax would provide a powerful signal for more cost-effective energy choices. In that respect, computable general equilibrium models probably overestimate the cost impacts of carbon/energy taxation. On the other hand, the assumption of cost-minimising behaviour in such models may exaggerate the adaptability of economic agents in responding to changes in energy prices.

According to many of these models, as summarised in IPCC, the aggregate economic cost of stabilisation at current levels in two decades would be in the order of magnitude of 1 per cent of gross domestic

product in the final year⁵⁴, with potentially significant differences across countries. These same modelling results also suggest that such differences in GDP losses could be reduced by equalising marginal reduction cost, for example with a common price signal.

Distribution issues

In introducing a new carbon/energy tax, distribution issues constitute a principal bone of contention. Absent massive CO₂ offset options, a tax on carbon/energy would particularly affect the fossil fuel sector, as well as energy-intensive industries. It is important to note that *any* policy aimed at reducing fossil fuel consumption would have a similar effect on the energy extraction and refining industry. Still, experience shows that the point where the tax is applied (at the mine mouth or at the utility busbar) affects the perception of costs among agents, and their support or opposition to the tax.

In terms of effects on different income groups, a carbon/energy tax, absent any compensating measures, could be regressive, with differences across countries coming from, among others, the reliance on personal vehicles, and the total energy mix in households energy consumption. Tax policies can be adapted to offset the regressivity of a carbon/energy tax.

Recycling options

National experiences with new carbon/energy taxes show practical ways to recycle tax revenues to alleviate the more negative effects of the tax on low-income groups. In most cases, the carbon/energy taxes have been introduced as part of a fiscal reform, aiming to lower taxes on capital and labour, while reducing energy-related externalities.

Modelling studies focused on short to medium term effects show that a low carbon tax, if properly recycled to reduce more distortionary existing taxes may result in a net macro-economic gain, i.e., an economic dividend in addition to the environmental dividend. Employer's paid social security contributions could be reduced to foster employment; the tax can also be recycled into investment tax credits, with positive effects on GDP, or to reduce government deficit.

There is not, however, a consensus on the existence of a double-dividend. For instance, macro-economic models accounting for unemployment find that recycling tax revenues through lower employers' paid social security contributions could offset the negative effect of the tax on GDP, through higher employment. Computable general equilibrium models which generally ignore unemployment find that recycling carbon/energy tax revenues would not offset the distortionary impact of a carbon/energy tax.

Carbon/energy tax revenues can be used to finance energy-efficiency improvements in an interim period, an option currently implemented in some European countries. Such measures contribute to minimise the increase in energy costs for energy-intensive activities, through a lowering of their carbon-intensity. Funding of research and development for low carbon/energy technologies could also be envisioned. If not introduced temporarily, such policies ought to be carefully monitored to ensure that they do not introduce permanent distortions in energy choices.

⁵⁴ GDP effects are expressed as a percentage reduction from the baseline for a given year, or as the present value of real income changes over the simulation period, relative to baseline levels.

Carbon sequestration as a joint-policy tool

This study briefly explores the possibility of offering a choice between paying a carbon tax or sequestering carbon through afforestation measures, when sequestration can be achieved at a lower cost per avoided ton of CO₂. Another option would be to use forestry measures to enhance the effectiveness of a carbon tax, through the recycling of tax revenues as an incentive payment for carbon sequestering. Such schemes would introduce some additional complexity; they would require further analysis especially if they are to be considered as an instrument to be used in conjunction with common taxation.

Feasibility

Any taxation scheme agreed at some international level would have to deal with most implementation issues experienced in setting carbon/energy taxation at the national level.

Experience shows that even “modest” homogeneous taxes on carbon and energy may be difficult to introduce in some Annex I countries, even when exemptions are granted, and other economic policy objectives could be obtained with the tax. The cost of an increase in taxation, directly perceptible by economic agents, does trigger significant political opposition, but this is not unique for taxation instruments. Exemptions for exporting industries, differentiated tax rates across agents, phased-in taxes and various recycling options are possible instruments to overcome some of the political barriers to taxation at the country-level, although they may lower the efficiency of the tax. On the other hand, the relative effectiveness of cross-cutting instruments, such as taxation, may help to overcome implementation obstacles.

In general, barriers to the implementation of a single uniform tax stem from national differences in energy mix and pricing, from sectoral differences in energy-use, and from distribution issues. End-uses such as transportation where taxes are already high in most countries, could absorb a modest price increase from a carbon/energy tax in those countries. Other sectors like industry and power generation are constrained in the near term by the lifetime of their physical capital. Different tax levels across activities and users, where risks of tax evasion were low, have been used in some instances. The progressive introduction of carbon/energy taxes, and a clear schedule for their evolution over time would help minimise the cost of reducing long-term CO₂ emissions. In some cases, existing taxes were replaced by taxes based on the carbon/energy content of the fuel, and increased on that basis afterwards.

A common approach to taxation might help reduce the opposition to a tax on competitiveness grounds. However, this is not the case for all Annex I countries, because not all Annex I countries primarily trade with other Annex I countries. For that matter, changes in competitiveness would not be similar for all Annex I countries. This issue is linked to the deliberations of the World Trade Organization on the possibility to introduce border tax adjustments on embodied carbon and energy,⁵⁵ as well as on the practicality and effectiveness of such adjustments.

The ongoing discussion within the European Union on proposals by the European Commission for a EU-wide carbon/energy tax shows the difficulty of obtaining an agreement on common taxation, also when significant flexibility for Member States to reach a uniform tax level in the future is provided.

⁵⁵ The Committee on Trade and the Environment of the World Trade Organisation is expected to address this issue before December 1996.

In addition to domestic implementation issues, countries may be reluctant to introduce a tax at a rate that will be set at some international level, which would take away their control over revenues of the common tax. The European Union member States agreed to follow the approach of using minimum levels of excise duties, which is already in place for mineral oils, to overcome this problem.

In practice, questions such as the exchange rates to be used for translating the common tax, the rules for its evolution given differences in exchange rates, inflation, and reduction levels achieved in participating countries, would require careful attention for the tax to be able to provide a steady price signal for energy choices.

The question whether to levy a carbon/energy tax at the level of producers or consumers will also require careful attention.

Time period

The purpose of a carbon/energy tax is to provide a steady price signal over time, so as to move away from carbon-intensive energy choices. Such a price-driven shift can only happen in the medium to long-term, due to the rate of capital stock turnover and existing infrastructures. This explains why in most cases, carbon/energy taxes are used as one instrument in a much broader package of policies aimed at reducing greenhouse gas emissions.

Taxes could be designed so as to best exploit different lifetime of capital stocks across sectors, e.g. through taxes that are phased-in at different rates. This would minimise the transitional costs of a tax. Any early retirement of existing equipment, which may be necessary to achieve national targets for reductions, comes with an opportunity cost. Providing temporary subsidies for energy efficiency improvements, e.g. through recycling of tax revenues, would help reduce such opportunity costs.

Impacts on other countries

Two issues could be considered: leakages (positive and negative) and border tax adjustments.

Leakages

Any reduction in fossil fuel demand to reduce CO₂ emissions in Annex I would entail a decrease in international prices of carbon-based fuels, beneficial to the rest of the world as a whole; carbon/energy taxation would also have that effect. Moreover, countries competing internationally with industries from with Parties with carbon/energy taxes would be granted a competitive advantage from their un-taxed energy, and become more attractive for investment in energy-intensive activities.

On the other hand, they might pay a higher price for imported goods from Annex I Parties implementing the tax, and be affected by other changes in their terms of trade. Modelling analyses disagree on the overall impact on non-participating countries and on their emissions. While their energy use and emissions may increase, their economic growth may be affected positively or negatively (lower exports to Annex I Parties, due to lower demand for fossil energy and possibly slower economic growth). Even the general direction of changes is uncertain, given the different assumptions on terms of trade, trade balances and the substitutability between domestic and imported goods.

Another aspect of leakages that is not studied in the literature is the possibility for non-participating countries to benefit from technological developments taking place in those countries implementing a carbon/energy tax. In the longer run, this spillover effect may help non-participating countries to reduce their energy-related CO₂ emissions (not to mention to have more efficient, competitive industries and economic infrastructure).

Border tax adjustments

In addition to the taxation of fossil fuel and other energy imports, which is common practice, Annex I Parties implementing carbon/energy taxes could decide to introduce border tax adjustments on their imports and exports, related to the embodied carbon/energy, to and from non-participating countries. This has not been the case so far, although it was included in the BTU tax proposal of the United States. The World Trade Organisation has yet to provide a definitive answer on this question.

If participating countries were to tax imports from non-participating countries to assure fair competition on their domestic market, they would affect the export revenues of non-participating countries. A careful analysis of embodied carbon in imports from non-Annex I Parties would be necessary to obtain an order of magnitude for the effect of a border tax adjustment on imports. The administrative requirements and technical practicality of border tax adjustments may be the greatest barriers to their implementation.

APPENDIX II. ASSUMPTIONS AND METHODS

The empirical part of this reports displays energy and carbon intensities, as well as increases in unit costs from a US\$100/tC carbon tax. Due to data availability reasons, the results from the empirical analysis refer to 1992.

The data in the graphs and tables showing carbon and energy intensities are calculated as kilograms of carbon from energy use and kilograms of oil equivalents per US\$ of value added. Energy use from different energy carriers are taken from IEA energy balances. No carbon emissions are assumed from combustion of renewables such as biomass nor from process emissions in the carbon and energy intensity figures. Indirect use of fossil fuels in electricity generation is included, however. This is done by using average fuel shares in electricity generation as weights, and assuming that increases in unit fuel costs are passed on to electricity prices. Value added data are converted to US\$ using current exchange rates.

Some industrial processes include non-fuel use of energy. This includes petroleum products and natural gas as feedstocks in the chemical and petrochemical industry. The fossil fuels are partly producing carbon emissions and partly being sequestered in the manufactured products. Carbon will subsequently be released from the product in waste treatment (burning or otherwise). In the empirical analysis, we have calculated cost effects in the case all feedstock are taxed and in the case where only the part of feedstocks giving rise to carbon emissions are taxed (Table 3). In the latter alternative, we have assumed 50 per cent sequestration of petroleum products feedstock and 80 per cent sequestration of natural gas feedstock. The IEA data does not contain feedstocks for United States chemical industry. In this case, feedstocks were calculated by multiplying fossil input in United States chemical industry by the feedstock fraction in Canada, assuming a similar input structure in the two countries' chemical industries.

In other industrial processes, such as production of aluminium, carbon (coke) is used as electrolyte in the chemical process. The available IEA data do not make it possible to account for such use of fossil fuels. In order to mitigate this deficiency, however, we have calculated carbon emissions from such processes by combining the process emission factor taken from the Norwegian aluminium industry with aluminium production in the different countries. In 1992, Norwegian aluminium production resulted in the emission of 0.52 tonne of carbon per tonne of aluminium in process emissions.