

International Carbon Agreements, EIS Trade and Leakage

March 2000
(revised)

Alan S. Manne
Stanford University

Richard G. Richels
EPRI

An earlier version was presented at Energy Modeling Forum 18, "International Trade Dimensions of Climate Change Policies", February 24-25, 2000. Helpful suggestions have been received from Paul Bernstein and Thomas Rutherford. For research assistance, the authors are indebted to James Deaker and to Robert Parkin. Funding was provided by EPRI. The individual authors are solely responsible for the results presented here.

See www.stanford.edu/group/MERGE for general information on the MERGE family of models. The following report provides an update of Appendix A to our paper that appeared in the May 1999 special issue of *The Energy Journal*.

Abstract

The MERGE model has been modified to include the possibility of changes in the location of production that are associated with international trade in EIS (the energy-intensive sectors). The new feature is introduced in a way that preserves the basic simplifying characteristics of MERGE. The intercept of the non-energy supply curve for EIS in each region may be described as a Heckscher-Ohlin fraction. The intercept of these supply curves serves the same purpose as an Armington elasticity describing substitution between foreign and domestic goods. This is the way in which we avoid penny-switching as a characteristic solution mode. At the same time, this avoids the usual difficulties with the Armington formulation when base-year trade quantities are small.

In qualitative terms, our conclusions are as follows:

- (1) Leakage is a distinct possibility, but it would not be large enough to wipe out the global effects of the carbon reductions to be undertaken by the Annex B countries under the Kyoto Protocol.
- (2) Leakage ratios are large enough to be worrisome.
- (3) Leakage ratios are sensitive to the numerical values of the EIS trade parameters.

Introduction

MERGE has been modified to include the possibility of changes in the location of production that are associated with international trade in EIS (the energy-intensive sectors). EIS is an aggregate including ferrous and non-ferrous metals, chemicals, nonmetallic minerals, paper, pulp and print. This aggregate does not include the energy-intensive industry of petroleum refining. The model may be run either with or without EIS trade.

The new feature is introduced in a way that preserves the basic simplifying characteristics of MERGE and of ETA-MACRO. That is, energy, capital and labor are substitutes that enter into a region-specific aggregate production function. They produce a numéraire good which may be used for consumption, investment and interindustry payments for energy costs. See Figure 1.

The GTAP (General Trade Analysis Program, 1992) data base is employed to estimate each region's initial EIS demands. According to Figure 2, each of the nine MERGE regions is sufficiently large to be nearly self-sufficient with respect to EIS. Net trade represents a relatively small amount of each region's total internal demand.

For projecting the impact of the Kyoto Protocol, each region is taken to be self-sufficient in EIS at base year energy prices. Changes in the location of production are attributed primarily to changes in the cost of energy. At base year prices in the USA, about 85% of the cost of EIS consisted of non-energy inputs (labor and capital charges, shipping, iron ore, etc.), and 15% of the cost consisted of energy inputs (half electric and half nonelectric). Under these conditions, a doubling of energy prices would imply only a 15% increase in the cost of EIS. This is why it is assumed that the demand for EIS is inelastic with respect to the price of energy. For projecting future demands, the income elasticity for EIS is taken to be 0.5.

The modified Heckscher-Ohlin model

The intercept of the non-energy supply curve for EIS in each region may be described as a "Heckscher-Ohlin fraction". If this intercept is unity, EIS is viewed as a perfectly homogeneous commodity. Small changes in energy costs will then lead to large changes in the international location of production. If the intercept is less than unity, the supply function is less elastic, and the changes in location will be less dramatic. (See Figure 3.)

HOFRAC denotes the Heckscher-Ohlin fraction, the relative price of imports at which domestic supplies drop to zero. Suppose that a region supplies most of its own demand domestically. It may then be shown that the supply elasticity of non-energy inputs to domestic EIS production = $1/(1 - \text{HOFRAC})$. E.g., in our reference case, the

long-run value of HOFRAC = .5, and the supply elasticity is 2.0. When HOFRAC is zero, the supply elasticity is 1.0.

The intercept of these supply curves serves the same purpose as an Armington elasticity describing substitution between foreign and domestic goods. This is the way in which we avoid penny-switching as a characteristic solution mode. At the same time, this avoids the usual difficulties with the Armington formulation when base-year trade quantities are small. To illustrate these difficulties, see Figure 4.

The figure provides a three-way comparison. On the left is a base case in which the prices of domestic and foreign inputs are identical. 95% of the inputs are domestic, and 5% are imported. This is used as a “benchmark” for estimating the parameters of both an Armington and a modified H-O (Heckscher-Ohlin) model. For both the middle and rightmost bars, there is a 50% decline in the relative cost of imports, and the output remains constant. With an Armington formulation and a CES (constant elasticity of substitution) of 3, this drastic decline in the cost of imports leads to only a moderate decline in the use of domestic inputs per unit of output. With a modified H-O formulation and HOFRAC = 0 (unitary supply elasticity), the change in relative prices leads to a much more drastic reduction of domestic inputs.

Perhaps more important, the modified H-O model avoids a perplexing feature of Armington. With Armington, Figure 4 shows that the price change leads to a 10% increase in the sum of the inputs (valued at base year prices), but there is no change with the modified H-O model.

To think about these two very different results, consider the case of steel reinforcing rods for construction. Assume that there are only minor international differences in quality. Then, except for transportation costs plus tariff and non-tariff barriers to trade, it should not really matter whether these rods are produced in China or in the USA. The total amount required for a construction project should remain the same. This characteristic surely favors the modified H-O over the Armington formulation for physically homogeneous commodities such as EIS.

Dispersion in energy coefficients

In these projections of energy coefficients per unit of EIS, we have taken note of informal communications from Paul Bernstein, David Montgomery and Thomas Rutherford. They find a wide regional variation in these coefficients. For modeling purposes, we have simplified their findings and represented them as shown in Figure 5. There, for example, in the year 2000, Japan’s energy coefficients are only 60% of those in the USA. By contrast, the coefficients in EEFSU (Eastern Europe and former Soviet Union) and also outside Annex B are 150% of those in the USA. Over time, it is assumed that these coefficients will all gradually converge toward the same values as

those in the USA.

For policy purposes, what is the significance of this dispersion in energy coefficients? Under the Kyoto Protocol, greenhouse gas limitations are imposed only on Annex B countries. On grounds of equity, the Protocol exempts non-Annex B countries from any obligation to restrict greenhouse emissions. Accordingly, they will have an artificial incentive to produce EIS – even though their energy and carbon coefficients may be higher than in Annex B. This is bound to exacerbate the problem of leakage – that is, an increase in non-Annex B emissions associated with a reduction in those of Annex B.

There is a further difficulty associated with the Kyoto Protocol. Annex B reductions will impose downward pressure upon international oil and gas prices. This will lower the export earnings of two of our major regions: EEFSU and MOPEC (Mexico + OPEC). These lower prices would stimulate the importing countries to increase their consumption of oil and gas. In EMF 18, it will be important to quantify and to compare these effects.

Preliminary findings

Four cases are compared here. The first two are those that have already been reported to EMF 18:

REF reference case – no international carbon limitation agreement – international trade in oil, gas, numéraire good and EIS.

NTC no trading of carbon emission rights between regions - Kyoto Protocol continued after 2010 throughout the planning horizon – otherwise identical to REF.

REIS EIS trade restricted to the same low volumes as in REF – otherwise same as NTC.

(The REIS case is useful for distinguishing between carbon leakage due to EIS and that due to oil and gas trade. At this point, MERGE does not provide for coal trade.)

HOFRAC=0 that is, unitary price elasticity of non-energy inputs to EIS supply; otherwise same as NTC.

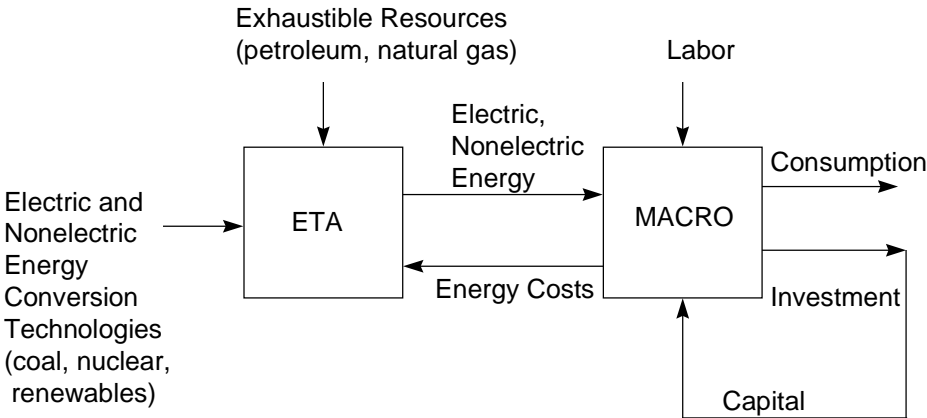
Figure 6 shows our estimate of the impact of Kyoto upon international oil prices. These prices rise with the exhaustion of oil and gas resources – and the eventual

establishment of a high-cost synthetic fuels industry. Over time, the REF prices rise even more than do those in the NTC case. This is consistent with our finding that the emissions leakage ratio associated with oil and gas trade also tends to rise over these years. (See especially Figure 9.)

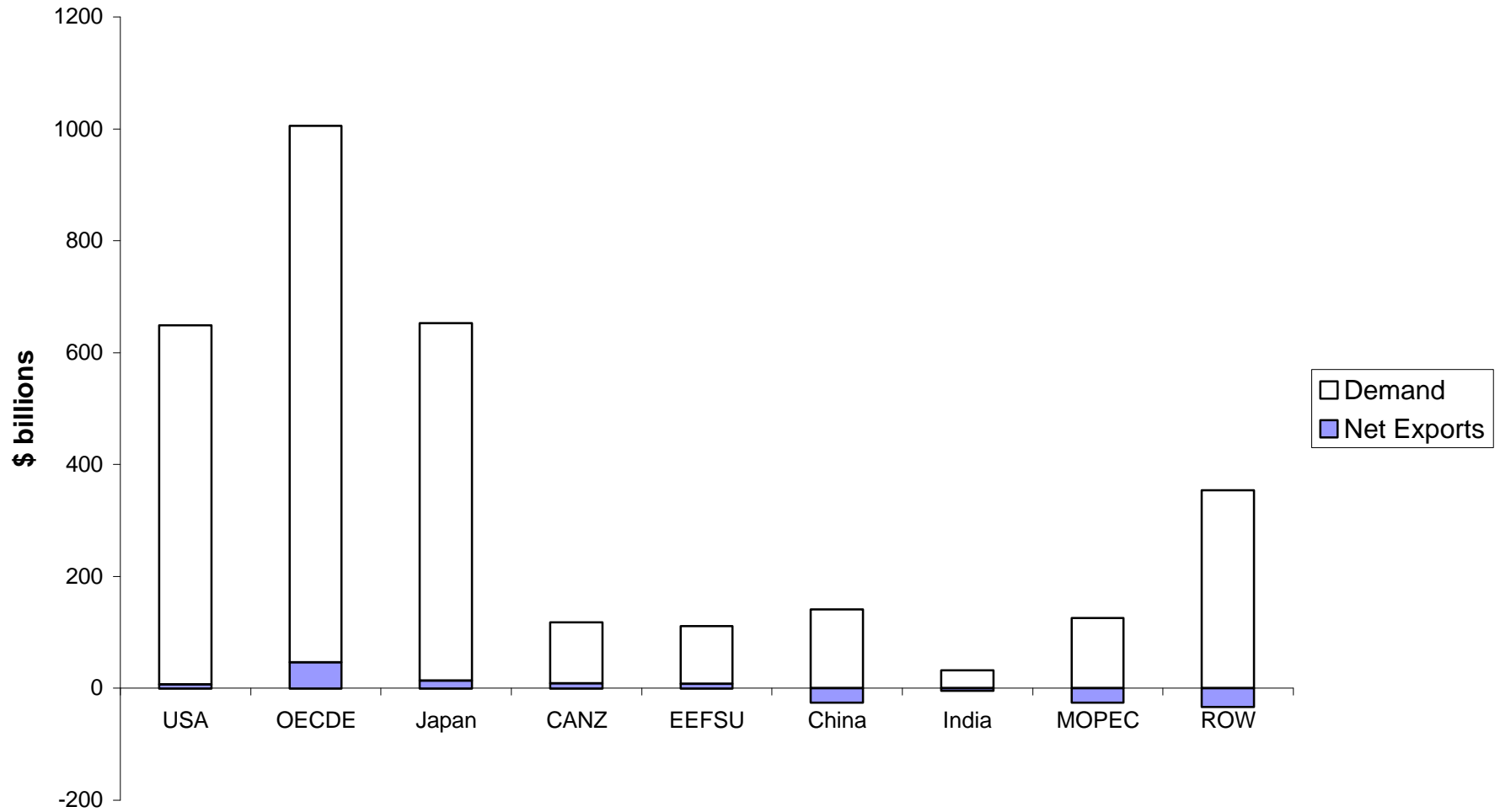
In qualitative terms, our conclusions from Figures 7-10 are as follows:

- (1) Leakage is a distinct possibility, but it would not be large enough to wipe out the global effects of the carbon reductions to be undertaken by the Annex B countries under the Kyoto Protocol.
- (2) Leakage ratios are large enough to be worrisome. During the early decades of the 21st century, leakage would be associated primarily with EIS trade. During the middle decades - with the international convergence of energy prices and also the convergence of the energy coefficients for EIS production - leakage would be associated primarily with trade in oil and gas.
- (3) Leakage ratios are sensitive to the numerical values of the EIS trade parameters. In the REF, NTC and REIS cases, HOFAC = .3 in 2010, and it rises to .5 by 2030. Figure 10 illustrates what might happen if we were to assume instead that HOFAC = 0. That is, the supply elasticity drops to unity in all time periods. The leakage ratio then declines significantly.

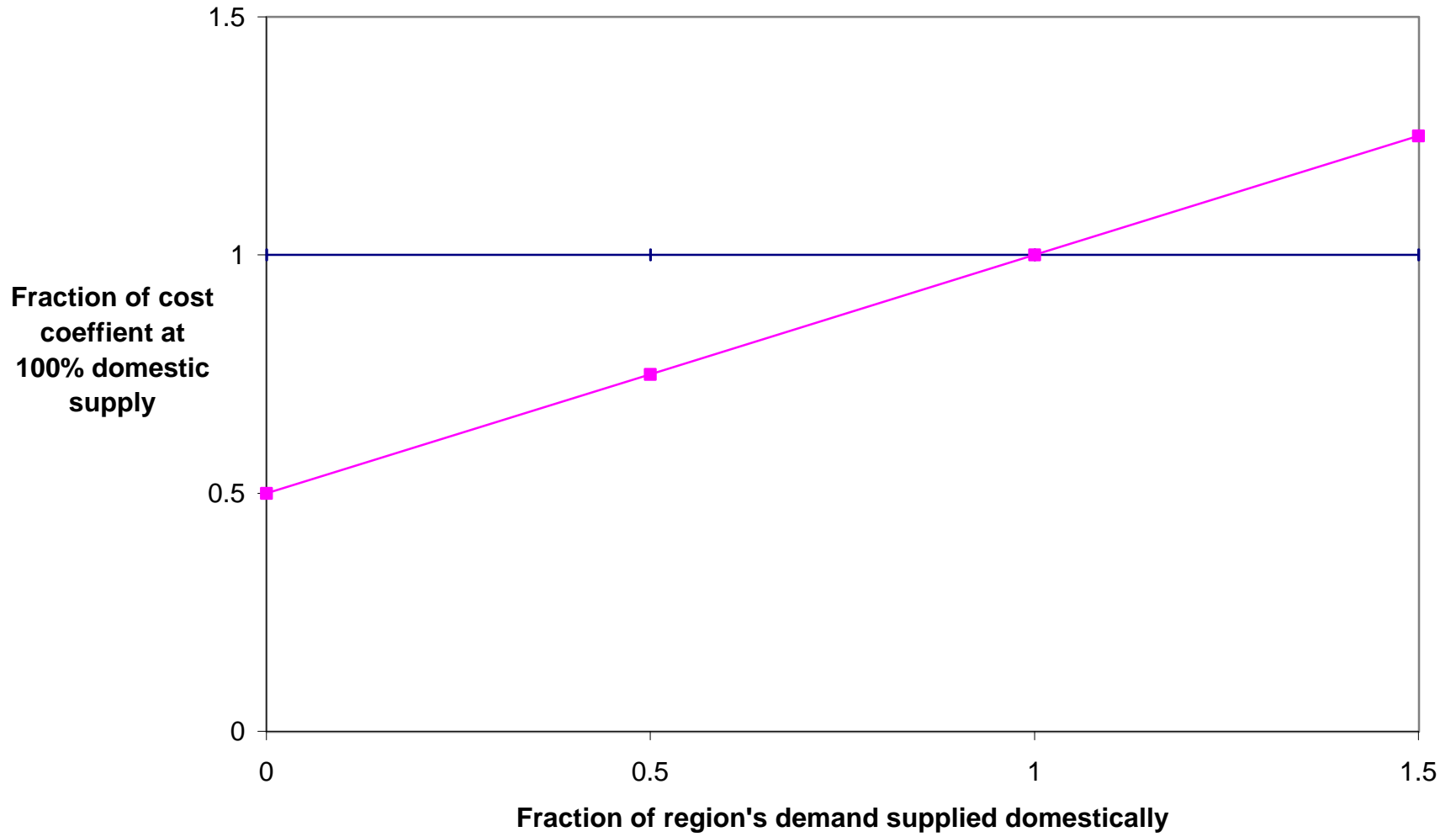
Figure 1: An overview of ETA-MACRO



**Figure 2: 1992 EIS demand and net exports
(GTAP, Global Trade Analysis Program,
Release 3, 1992)**



**Figure 3: EIS Supply Curves -
Marginal Cost of Non-Energy Inputs to EIS**



**Figure 4: Comparison between Base, Armington and modified Heckscher-Ohlin
(50% decline in relative cost of imports)**

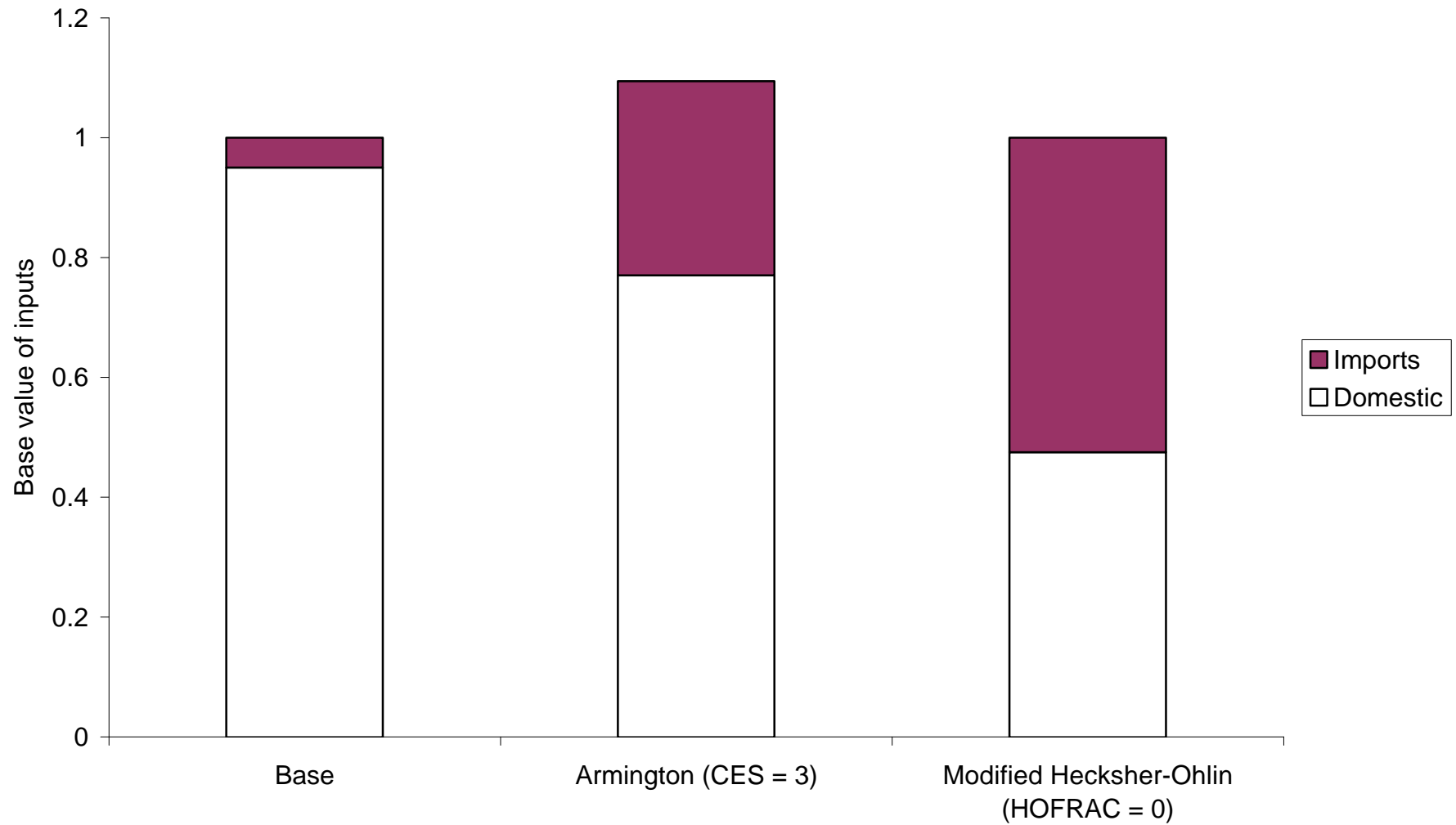


Figure 5: Energy Coefficients Relative to USA

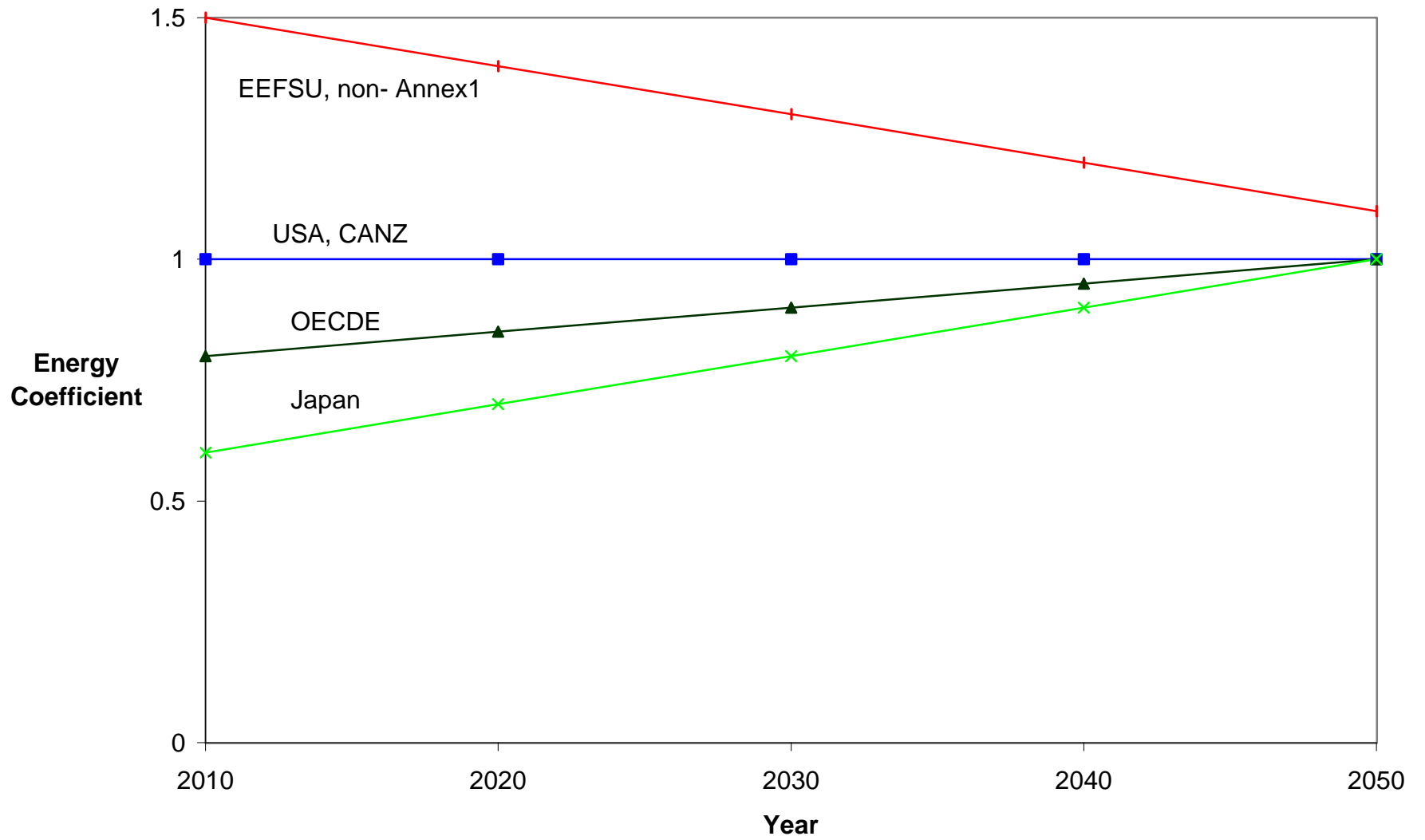
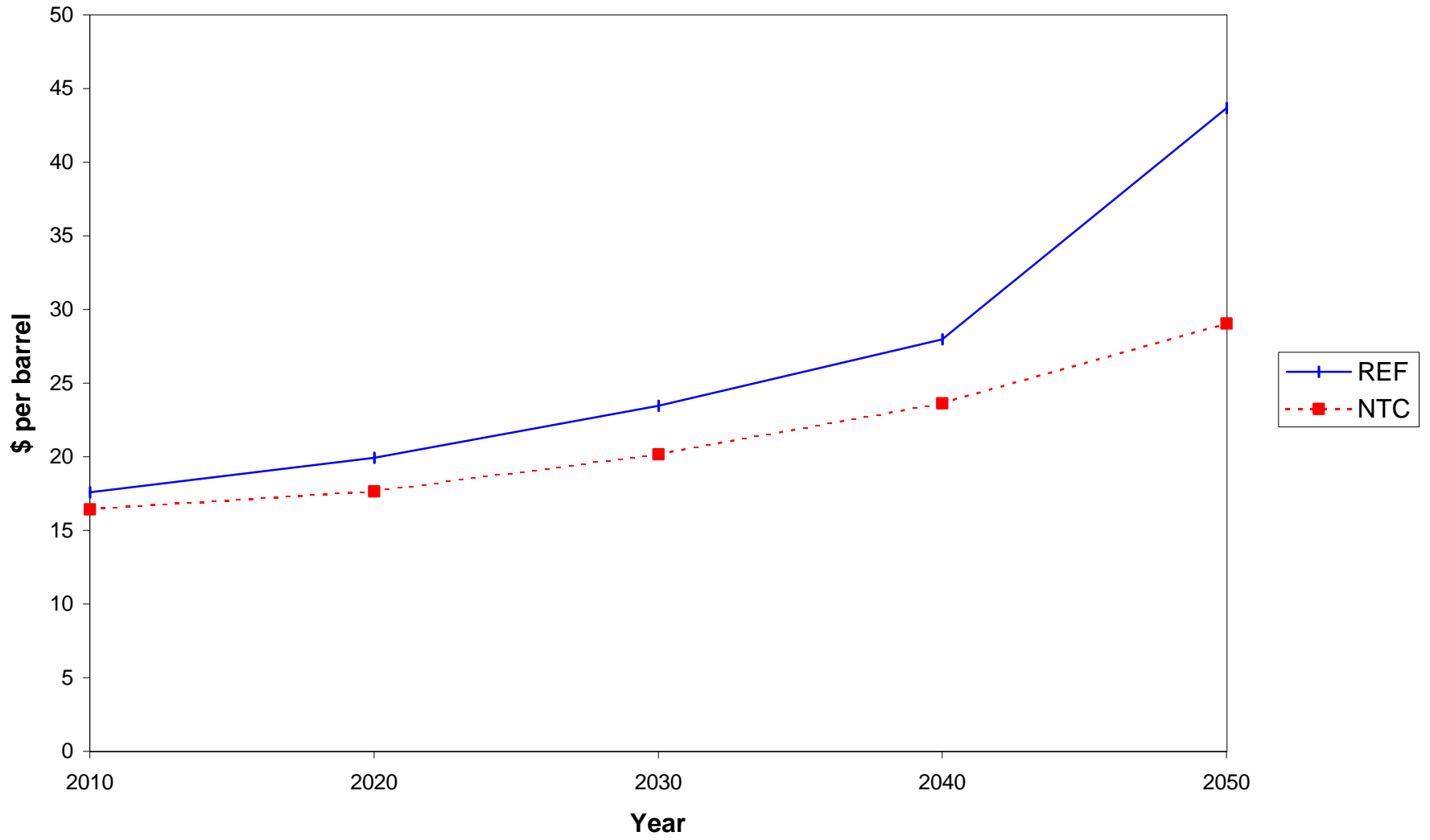
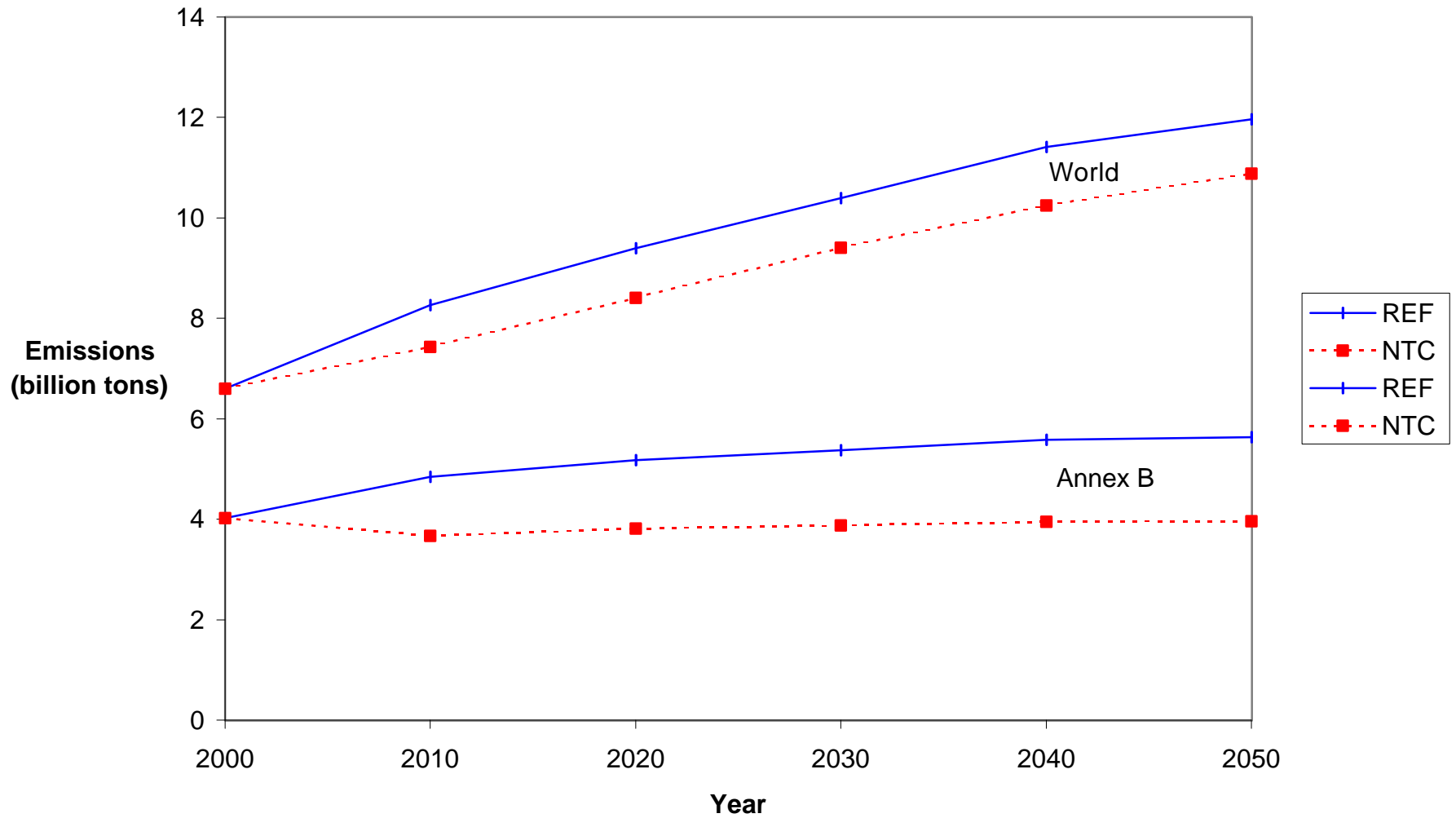


Figure 6: Oil prices - REF and NTC cases



**Figure 7 : Carbon Emissions in Annex B and World Total -
REF and NTC cases**



**Figure 8: Carbon Emissions Outside Annex B -
REF and NTC cases**

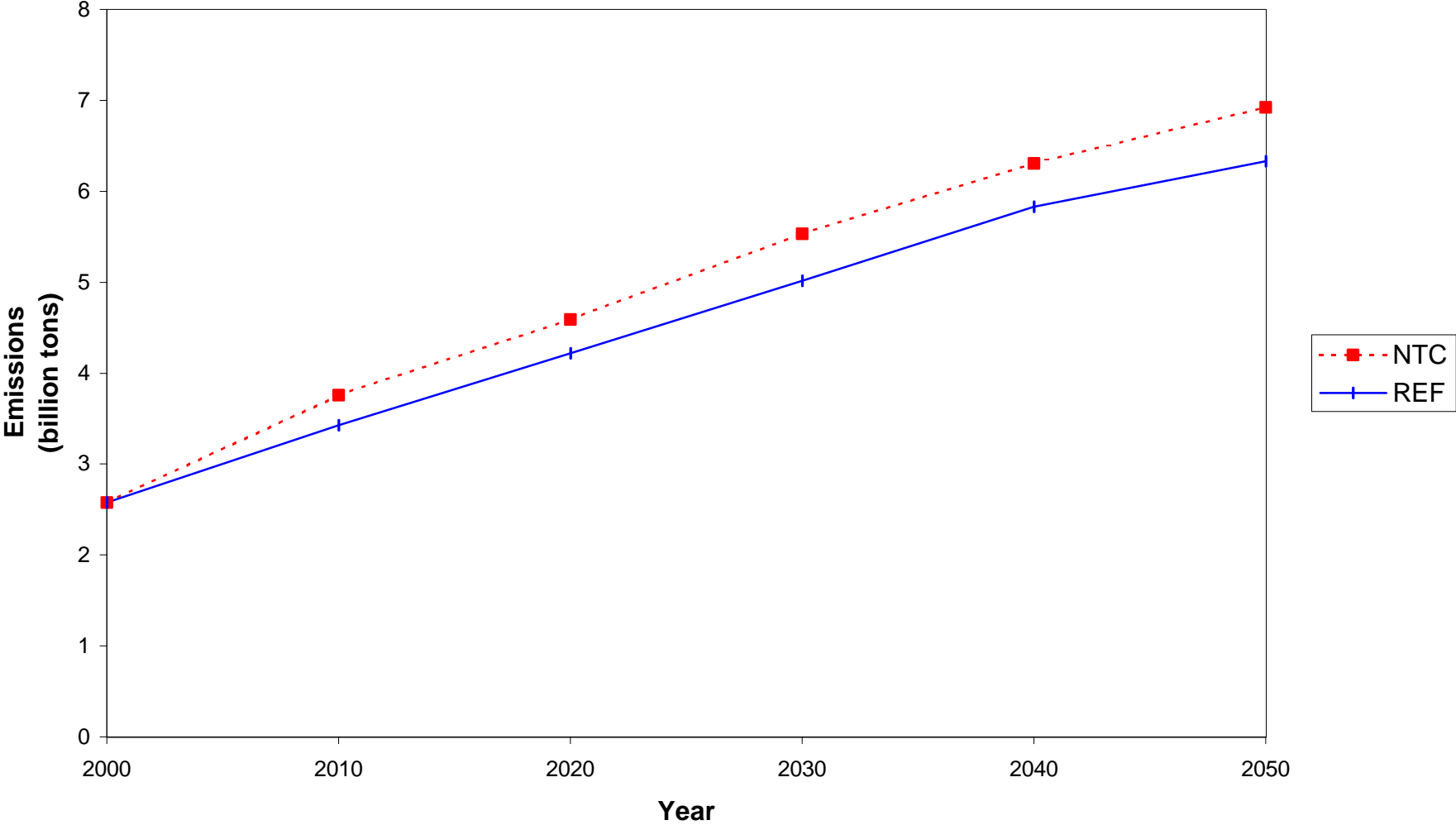


Figure 9: Leakage ratios, % - NTC and restricted EIS trade cases

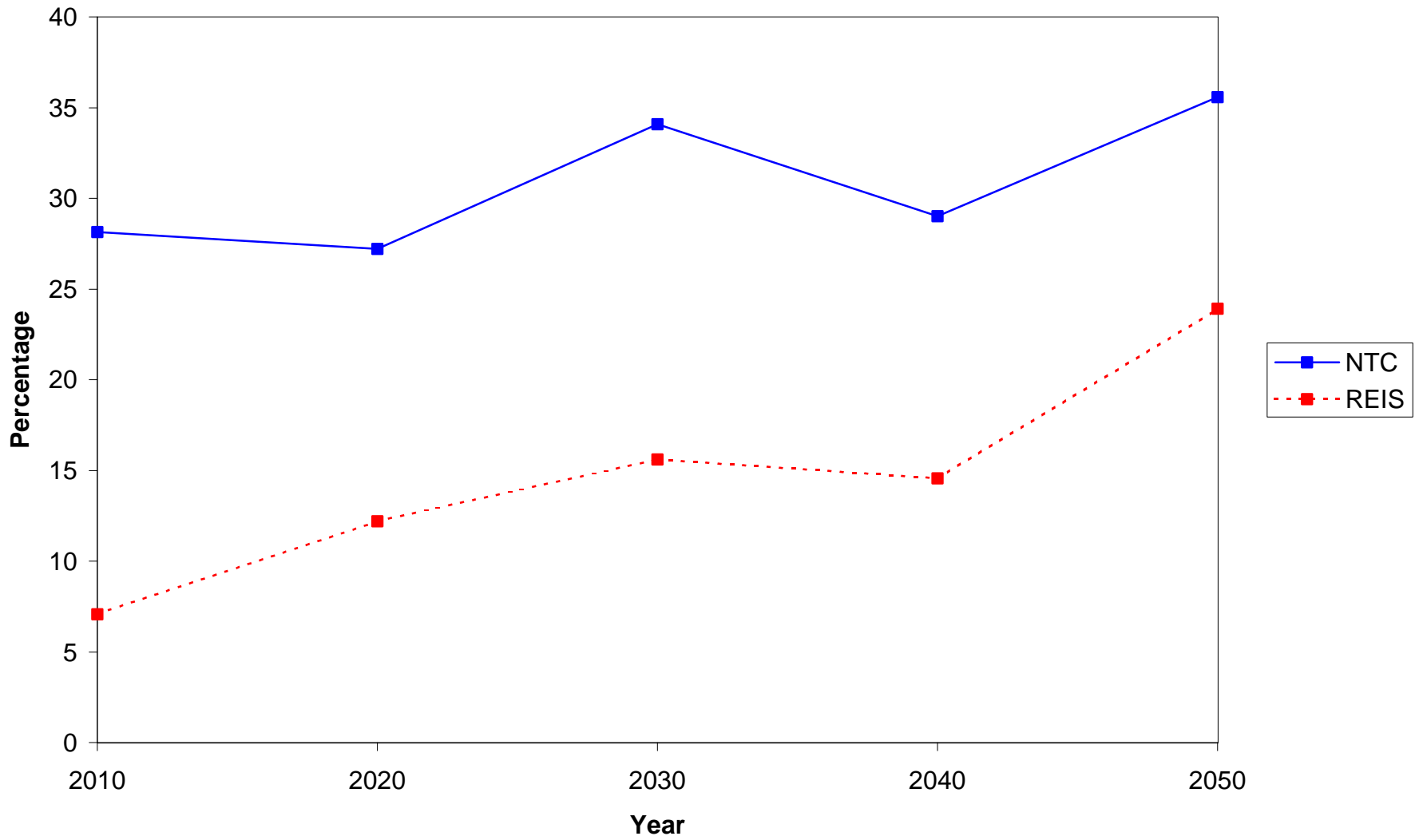


Figure 10: Leakage ratios, % - NTC and zero HOFRAC cases

