TRADE IN CARBON AND THE EFFECTIVENESS OF CARBON TARIFFS

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Abstract

In the absence of a global agreement to reduce CO2 emissions single countries or regions have introduced subglobal climate policies. One major challenge associated with unilateral action is carbon leakage, i.e., the relocation of emissions from regulated to unregulated regions. A principal measure to combat carbon leakage is carbon tariffs, where embodied emissions in imports are taxed at the domestic CO2 price when crossing the border. Using combined MRIO and computable general equilibrium (CGE) analysis for the years from 1995 to 2007 based on data provided by World Input-Output Database (WIOD), we assess the potential of carbon tariffs as a means of improving the global cost-effectiveness of unilateral emission pricing. Our MRIO analysis shows increasing relevance of embodied carbon in trade. Both imports of embodied carbon in OECD countries and exports of embodied carbon from developing countries have increased substantially. However, our CGE policy simulations suggest that the effectiveness of carbon tariffs does not increase over time but the burden shifting potential from OECD to Non-OECD countries increases.

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1. Introduction

In spite of the substantial increase in carbon trade via international trade in recent years (Peters and Hertwich 2008, Peters et al. 2011) with consequential effects on the environment, the likelihood of a global agreement to mitigate emissions embodied in trade seems very bleak. A critical drawback associated with unilateral action to combat global CO2 emission is the so called carbon leakage – the relocation of emissions from regulated to unregulated regions – due to international spillovers from fossil fuel markets and a decline in the competiveness of energy-intensive and trade-exposed (EITE) sectors. Given the global nature of the CO2 externality and the fact that only global CO2 emissions matter for climate protection, carbon leakage worsens the cost-effectiveness of unilateral policies. Thus, within the context cost-effectiveness and competitiveness concerns, carbon tariffs – taxation of emissions embodied in imports based on the domestic CO2 price – have emerged as the most popular trade measure that is envisaged to lessen drawbacks of unilateral action.

Aside the prospects of reducing carbon leakage and hence ameliorating anxieties regarding the loss of competitiveness in domestic industries, advocates also point out that unilateral policies geared towards emission abatement solely in domestic production sectors ignore the carbon footprint of imported goods and therefore amounts to shirking of responsibilities. This argument stems from numerous empirical evidences showing that OECD countries are net importers of embodied carbon as their citizens consume imported goods with embodied emissions while developing countries are net exporters.

Aside being effective at minimizing leakage, carbon tariffs may be effective at increasing the coverage of unilateral climate policies even with limited participation, consistency between consumption and environmental impacts and also increasing mitigation options. However, beyond the legal and political considerations, the elegance of embodied carbon tariffs is also hampered by the fact that it imposes substantial burden of emission reduction from abating to non-abating countries (Böhringer et al. 2011). Thus, under border carbon adjustment, the deterioration of the terms-of trade for non-abating countries becomes more pronounces while abating countries enjoy terms-of-trade gains.

In this paper we assess the ***potential of embodied carbon tariffs as a means of improving the global cost-effectiveness of unilateral emission reduction against the background of an increasing relevance of embodied carbon in trade***. We address this by using a combined multi-region input-output (MRIO) and computable general equilibrium (CGE) analysis for the years 1995 to 2007 based on data provided by World Input-Output Database (WIOD). Results from our MRIO analysis show an increasing relevance of embodied carbon in trade. Both imports of embodied carbon in OECD countries and exports of embodied carbon from developing countries have increased substantially between 1995 and 2007. A decomposition of carbon embodied in final products of energy-intensive and trade-exposed sectors in the OECD shows that the share of carbon stemming from imported intermediate inputs increased from about 12% in 1995 to more than 20% in 2007. However, our CGE policy simulations suggest that the effectiveness of carbon tariffs does not increase over time but the burden shifting potential from OECD to Non-OECD countries increases.

The remainder of our paper is organized as follows. In section 2, we describe the data, numerical models (MRIO and CGE models) and policy scenarios. In section 3, we present our results and draw our conclusions in section 4.

2. Data, numerical models and policy scenarios

Data

Our analysis is based on the World Input-Output Database (WIOD). It provides time-series of detailed input-output tables and trade flows as well as socio-economic and CO2-related satellite data for the time period of 1995 to 2009. The database incorporates 41 world regions and 35 sectors of the economy (Timmer 2012). For our numerical analysis, we aggregate the data to 13 regions and 13 sectors towards the specific research question. The regions and sectors are shown in Table 1. We explicitly represent the energy carriers fossil fuels (in the sector mining and quarrying), refined oil products and electricity. Also, we incorporate the most energy-intensive and trade-exposed industries as they are subject to carbon tariffs in the policy scenarios, see below. As to regions, we represent industrialized economies potentially going ahead with unilateral climate policies (OECD countries) as well as the major developing economies.

Table 1: Model sectors and regions

Sectors and commodities	*Countries and regions*
Energy	*OECD*
Mining and quarrying	USA
Refined oil products*	European Union (EU 27)
Electricity, gas and water supply	Canada
*Emission-intensive & trade-exposed sectors**	Japan
Rubber and Plastics	South Korea
Basic metals and fabricated metal	Australia
Chemical products	Mexico
Non-metallic minerals	*Non-OECD*
Paper, pulp and print	Russia
Transport sectors	India
Air transport	Indonesia
Water transport	China (incl. Taiwan)
Other transport	Brazil
Other industries and services	Rest of the world
Agriculture	
All other manufactures and services	

* Included in the group of *energy-intensive and trade-exposed industries* (EITE).

Multi-region input-output model

In order to calculate the region- and sector-specific carbon content of goods we use input-output accounting identities for output and imports in each region. After solving the occurring linear system of equations, we can decompose the embodied emissions in goods according to their origin, i.e. whether they stem from the production process (through fossil fuel inputs) or are embodied in domestic or imported intermediate inputs.

Computable general equilibrium model

Computable general equilibrium (CGE) models are used in applied policy analysis because they represent markets micro-consistently and incorporate price-responsive supply and demand decisions. We use a standard static CGE model of global production, consumption and trade. Primary factors in the model are labor, capital and fossil resources. Capital and labor are intersectorally mobile but not interregionally. Fossil resources are specific to the mining and quarrying sector in each region. Final consumption in each region is realized through a representative agent who receives income from the primary production factors and maximizes welfare subject to his income constraint.

Production of goods other than fossil resources is captured through a three level nested constant elasticity of substitution (CES) function. At the top level, a material composite substitutes with a composite of value-added and energy. The second level describes the trade-off between value-added and energy. At the third level, labor and capital form the value-added composite. At the same level the energy goods – electricity, fossil resources and refined oil products – trade off in the energy aggregate.

In fossil resource production, the specific resource trades off with a Leontief composite of all other inputs. The top-level elasticity is calibrated to match an exogenous supply elasticity for fossil resources. Government and investment demand are fixed at exogenous real levels. Investment is paid by savings of the representative agent while taxes pay for the provision of public goods and services.

International trade is modeled following Armington's differentiated goods approach, where goods are distinguished by origin (Armington, 1969). The Armington composite for a traded good is a CES function of an imported composite and domestic production for that sector. The import composite in each country is again a CES function of production from all other countries. A balance of payment constraint fixes the base-year trade deficit or surplus for each region. CO2 emissions are linked in fixed proportions to the use of fossil fuels. Restrictions to the use of CO2 emissions in production and consumption are implemented through exogenous emission constraints. CO2 emission abatement then takes place by fuel switching (interfuel substitution) or energy savings (either by fuel-non-fuel substitution or by a scale reduction of production and final demand activities).

For model parameterization we follow the standard calibration procedure in applied general equilibrium analysis. The base-year input–output data determines the free parameters of the cost and expenditure functions such that the economic flows represented in the data are consistent with the optimizing behavior of the economic agents. The responses of agents to price changes are determined by a set of exogenous elasticities, which are not provided by the WIOD. These are taken from the pertinent econometric literature and the GTAP 8 database (Narayanan et al. 2012). The elasticities of substitution in fossil fuel sectors are calibrated to match exogenous estimates of fossil-fuel supply elasticities (Graham et al., 1999; Krichene, 2002; Ringlund et al., 2008).

Policy scenarios

In each year of the considered time periods we simulate two alternative climate policies. In our reference case – denoted REF – the OECD countries jointly reduce domestic CO2 emissions by 20% compared to their benchmark emissions. This is achieved through a uniform CO2 price within the OECD, which is equivalent to an OECD-wide trading scheme or a uniform OECD-wide CO2 tax. In the second climate policy – denoted TRF – the OECD countries additionally introduce a carbon import tariff, that is, a tariff on the imported embodied carbon at the domestic CO2 price. In order to conduct meaningful global welfare analysis, we hold the global level of emissions constant between REF and TRF for each year. This implies that that the reduction target within the OECD endogenously adjusts, such that the same level of emissions is met as in the respective REF case. By holding the level of emissions constant for each year we circumvent an assessment of damages through emissions in our welfare analysis.

3. Results

A. MRIO analysis

We begin our analysis by investigating the development of carbon embodied in global trade for the period 1995 to 2007. We present the evolution of net imports and exports of embodied carbon for developed countries (OECD) and emerging economies (BRIC) in Figure 1. Based on our MRIO results, we observe significant increases in both net export for BRIC countries and net imports for OECD. Figure 1 shows that the net imports of embodied carbon in OECD countries roughly tripled from an initial level of about 620 MT to over 1600 MT while net exports from BRIC countries doubled between 1995 and 2007. This is suggestive of the substantial increases in carbon trade over the last two decades with industrialized countries being large net importers of embodied carbon and developing countries being large net exporters.

Figure 2 shows the decomposition of the embodied carbon in an average good that was produced in the energy-intensive and trade-exposed sector in the OECD. “Direct” refers to emissions from fossil fuel inputs, “Domestic” to carbon embodied in domestic intermediate inputs and “Imported” to carbon embodied in imported intermediates. Figure 2 shows a decrease of the carbon content of an average EITE good produced in OECD countries in the period 2002 to 2007. While in 2002 an EITE good was produced with 1.1 kg per USD of output, this value dropped to 0.7 in 2007.

Figure 1: Net imports of embodied carbon in OECD and net exports of embodied carbon in BRIC

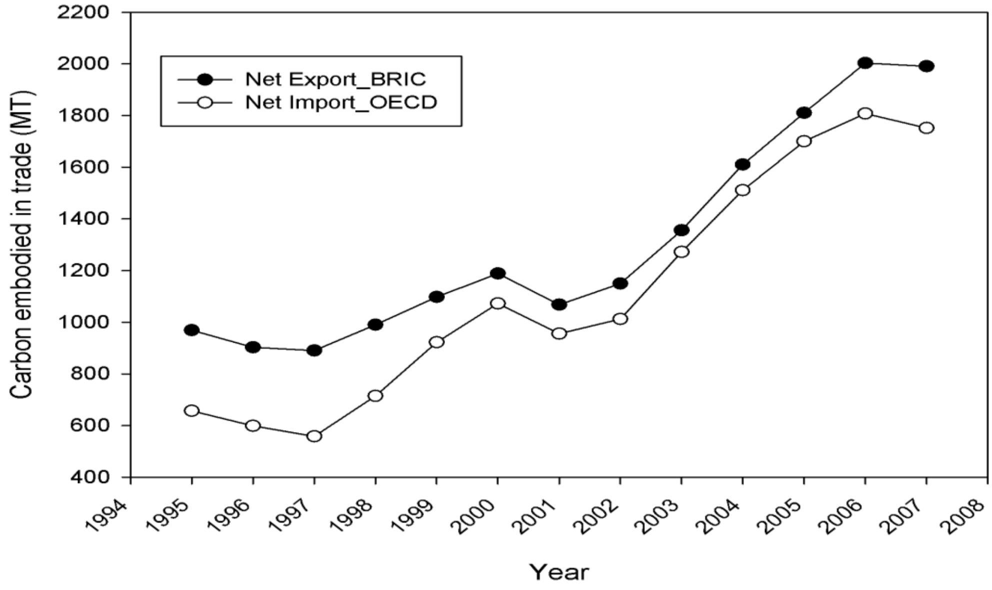


Figure 2: Decomposition of the carbon content of an average EITE good in the OECD

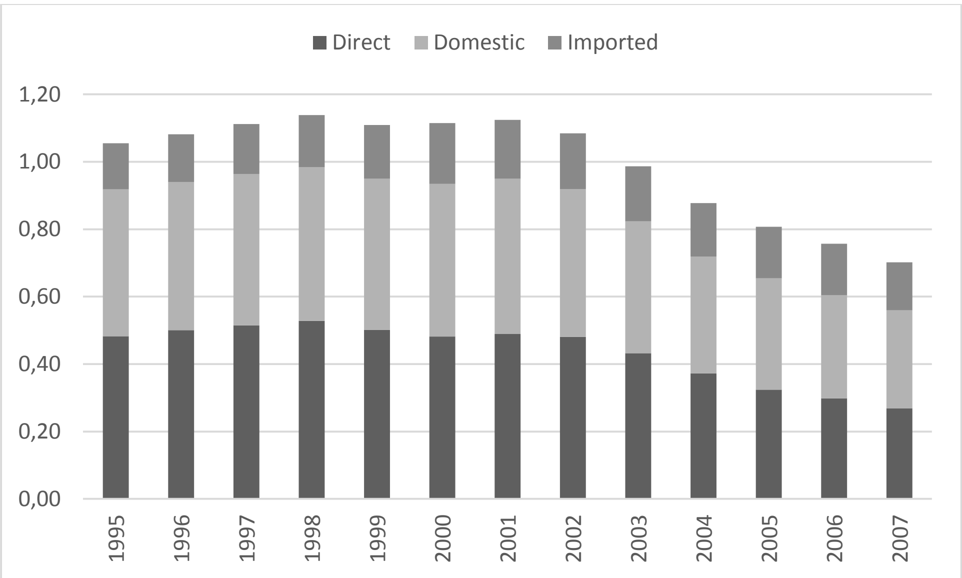
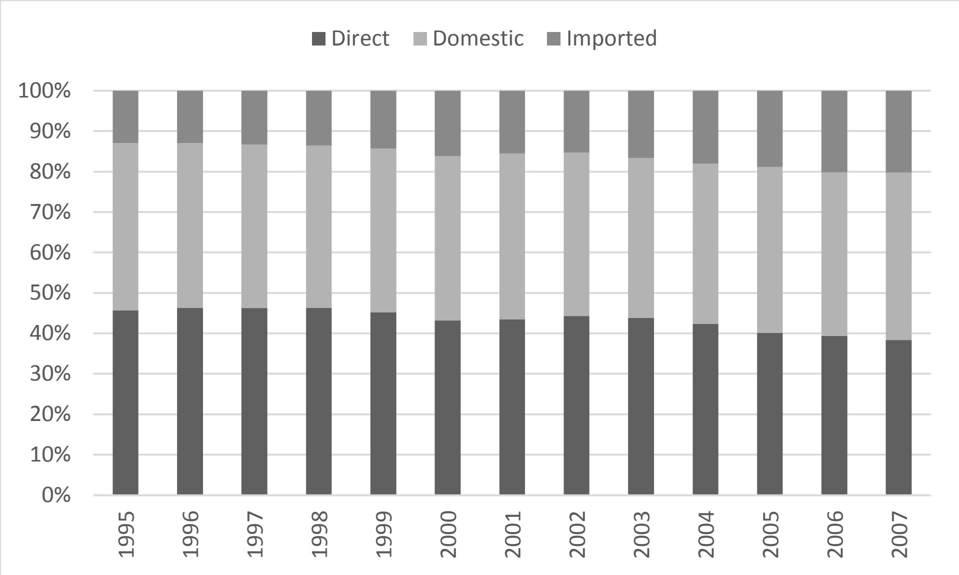


Figure 3 shows the same decomposition in percentage shares. While the share of direct emissions has decreased by about 5 percentage points over the period under consideration, the share of emissions produced from domestic intermediate inputs has remained relatively stable. However, the share of embodied carbon stemming from imported sources has increased from about 12 percent in 1995 to approximately 20 percent in 2007.

Figure 3: Percentage decomposition of the carbon content of an average EITE good in the OECD



B. CGE analysis

We begin our analysis by looking at the leakage rates[1] in our policy scenarios, see Figure 3. If we first consider uniform CO2 pricing (REF), we find that leakage is of increasing relevance. Between 1995 and 2007 we see a steady increase in the leakage rate, which roughly doubled from 4.6% to 9.4%. Higher leakage rates go along with higher CO2 prices within the OECD, in particular in the time period of 2002 to 2007, as shown in Figure 5. With a decreasing carbon content of goods produced in OECD's EITE industries (recall Figure 2), more effort is required to achieve the 20% reduction target. This is mirrored by increasing CO2 prices. This in turn induces a larger negative demand shock on fossil fuel markets due to the climate policy, which stimulates consumption in regions without emissions regulation. Furthermore, incentivizing the relocation of emission-intensive industries to unregulated regions. With a tariff in place (TRF), the leakage rate is lower than under REF throughout. From 1995 to 2000 the carbon tariff reduced leakage to below 2%. From 2001 to 2007 the carbon tariff reduced leakage by 3-4 percentage points in each year, thus became less effective in reducing leakage in relative terms. While in 2001 more than half of the leakage rate under the REF scenario is attenuated through carbon tariffs, in 2007 the tariff reduces the REF leakage rate by less than one third.

[1] Leakage is defined as the increase in CO2 emissions in unregulated regions as a percentage share of the decrease in CO2 emissions in the region that is introducing a climate policy.

Figure 4: Leakage rates under REF and TRF

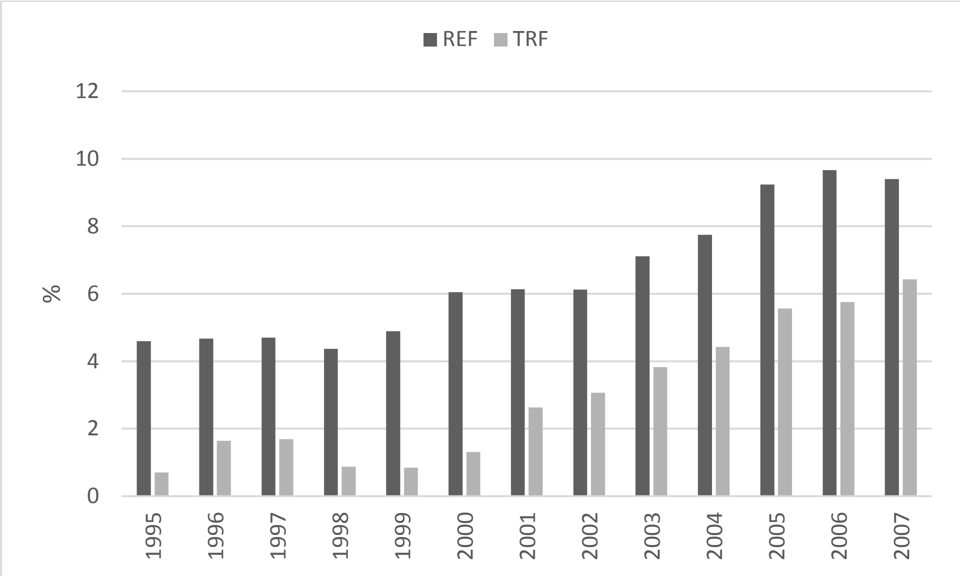
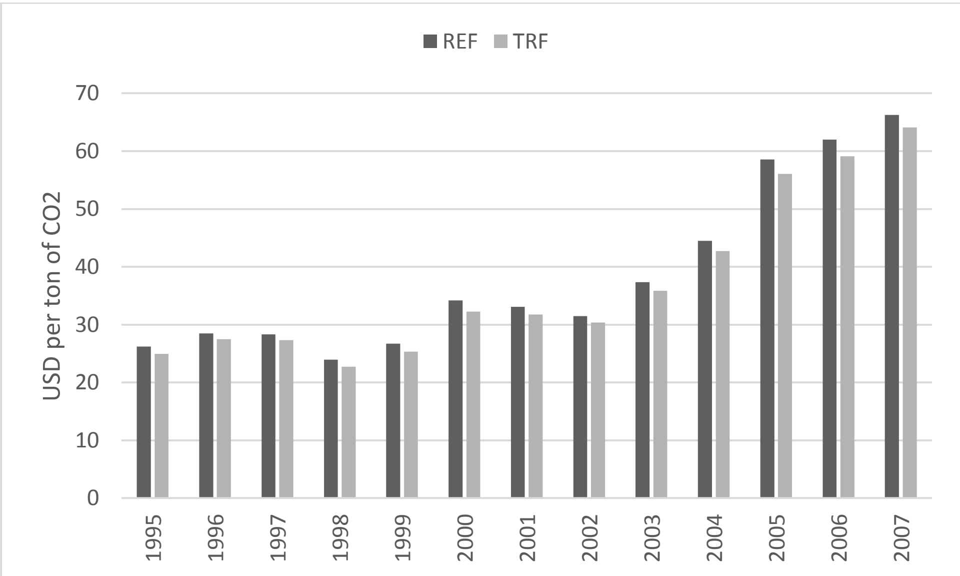


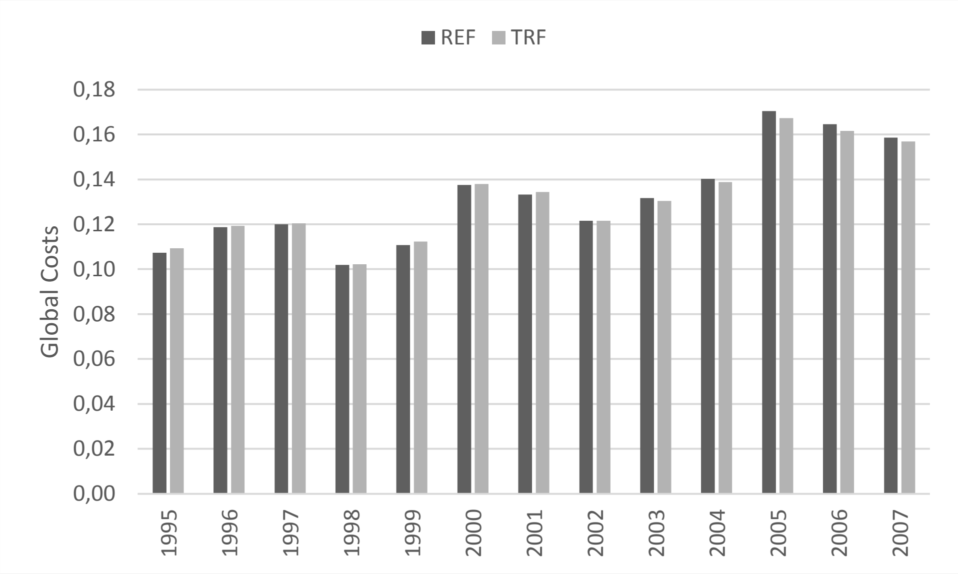
Figure 5: CO2 prices under REF and TRF



In terms of global cost-efficiency[2], carbon tariffs only show very moderate effects in our analysis, as shown in Figure 6. While from 1995 to 2001 the introduction of tariffs even slightly increases global costs compared to REF, it slightly decreases costs for the years 2002 to 2007.

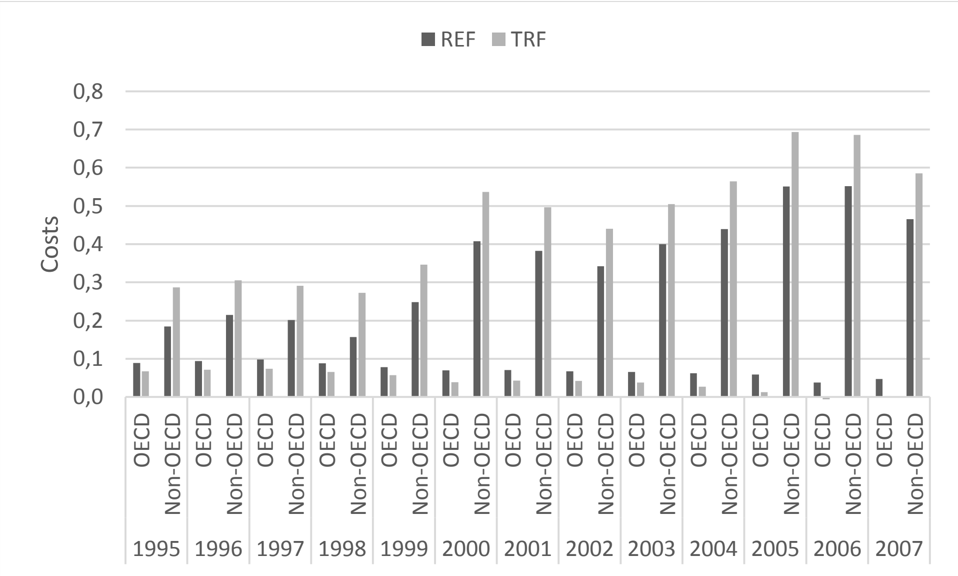
[2] In our analysis, we measure global costs as Hicksian equivalent variation as percentage share of benchmark income. Costs in our case are always positive because we don't assign monetary values to emissions reduction.

Figure 6: Global costs under REF and TRF



In spite of rather small effect of carbon tariffs on the global costs, the effect on the distribution of costs between OECD and Non-OECD countries is however quite significant, see Figure 7. In both absolute and relative terms the OECD countries shift over more of the costs of abatement to the Non-OECD countries. The carbon tariff increases along with the CO2 price, turning the terms-of-trade in favor of the OECD.

Figure 7: Costs in OECD and Non-OECD countries under REF and TRF



4. Preliminary conclusion and outlook

In our calculations in Section 3 we found substantial increases in carbon trade, particularly net imports of carbon into OECD countries and net exports from developing countries. Based on these results we expected a significant and increasing effectiveness – and thus increasing relevance – of carbon tariffs in unilateral climate policy of OECD countries. In terms of leakage and global cost-efficiency, however, our CGE policy simulations suggest that the effectiveness of carbon tariffs does not increase over time. On the other hand, the burden shifting potential increased from 1995 to 2007. This is due to increasing gains in terms-of-trade for OECD countries.

These results are preliminary. A more detailed analysis is still ongoing.

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