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Climate policies for road transport revisited (II): Closing the policy gap with cap-and-trade

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ABSTRACT

Current policies in the road transport sector fail to deliver consistent and efficient incentives for greenhouse gas abatement (see companion article by Creutzig et al., 2010a). Market-based instruments such as cap-and-trade systems close this policy gap and are complementary to traditional policies which are required where specific market failures arise. Even in presence of strong existing non-market policies, cap-and-trade delivers additional abatement and efficiency by incentivizing demand side abatement options. This paper analyzes generic design options and economic impacts of including the European road transport sector to the EU ETS. The point of regulation in a road transport cap-and-trade system should be upstream in the fuel chain to ensure effectiveness (cover all life-cycle emissions and avoid double-counting), efficiency (incentivize all abatement options) and low transaction costs. Based on year 2020 marginal abatement cost curves from different models and current EU climate policy objectives we show that in contrast to

conventional wisdom road transport inclusion would not change the EU ETS allowance price. This puts concerns over industrial carbon leakage as a consequence of adding road transport to the EU ETS into perspective.

Keywords: Climate Policy, Road Transport, Cap-and-trade

1. Introduction

Road transport greenhouse gas emissions are rising around the world (IEA, 2008, 2009). Ambitious climate policy objectives such as limiting global warming to 2°C (UNFCCC 2009) require substantial emission reductions in all economic sectors, including road transportation (Luderer et al., 2010; Creutzig and Edenhofer, 2010). Decarbonizing the road transport sector will require new technologies and alternative fuel chains potentially including biofuels, electricity, natural gas or hydrogen.

A companion article by Creutzig et al. (2010a) provides an overview of life-cycle emissions of alternative road transport fuel chains. The article explores the consequences of fuel chain diversification for an effective and efficient road transport climate policy portfolio and reviews major current policies. The main finding is that current road transport policies in Europe, the United States and China have proved effective in reducing emissions but fail to set consistent incentives across all abatement options. Market-based instruments such as a carbon taxation or cap-and-trade system would close the prevailing gap in the climate policy portfolio, while traditional non-market policies will continue to play an important complementary role in addressing market failures beyond the greenhouse gas externality.

Several world regions including the United States, California, Japan, Canada, Australia, or New Zealand are discussing or implementing cap-and-trade systems that would include the road transport sector in an economy-wide trading system (Kossoy and Ambrosi, 2010). The EU Emission Trading System (EU ETS) does not include road transport but will cover aviation from 2013 (EC, 2008b). Against this background, this article reviews the theoretic rationale and practical design of cap-and-trade for the road transport sector and provides an empirical assessment of road transport inclusion to the EU ETS.

Peer-reviewed analyses of road transport inclusion to cap-and-trade are scarce. Raux (2005) focuses on a scheme covering final fuel consumers despite the substantial transaction costs associated with regulating millions of actors. Studies published as gray literature almost consistently omit the diversification of fuel chains (Creutzig et al., 2010b).

The remainder of this paper is structured as follows: Section 2 reviews the merits and demerits of market- and non-market-based policies for regulating road transport emissions. Building on the finding that market-based policies are an essential part of the road transport climate policy portfolio, Section 3 analyzes the relative merits of carbon taxes and cap-and-trade systems. As cap-and-trade is preferable under empirically plausible conditions, section 4 discusses key design issues in cap-and-trade implementation in the road transport sector, in particular the optimal point of regulation. Section 5 compares price and quantity effects of road transport integration into the EU ETS when using marginal abatement cost curves from several models. Section 6 concludes.

2. Market-based versus non-market instruments

Implementing market-based instruments such as carbon taxes and cap-and-trade systems to put a price on greenhouse gas emissions is a standard economic prescription in climate policy (Kalkuhl and Edenhofer, 2010; Nordhaus, 2008; Stern, 2007). A properly designed carbon price internalizes the emission externality and, in theory, incentivize *all* abatement options up to the *same marginal costs of abatement* (MAC). Therefore, market-based instruments are particularly suited for efficient climate policy. If the carbon price is credibly announced to persist over time, it will also foster dynamic efficiency as it stimulates research and development (R&D) efforts, market introduction of new technologies, and longer term behavioral adjustment (Edenhofer et al., 2006). Market-based instruments enable the regulator to directly control emission levels, either via an

emission cap or an adjustable carbon tax. From an industry perspective, a carbon price that is harmonized within and across sectors creates a level 'carbon playing field' for all firms. Market-based instruments enable the regulator to harmonize marginal abatement costs without need for assembling detailed techno-economic information which reduces the informational requirements.

Non-market instruments such as technology standards, by contrast, will typically address only specific abatement options and face difficulties in guaranteeing that marginal abatement costs are harmonized within and across sectors (Creutzig et al., 2010a). Some options for abatement may be harnessed at suboptimal levels or even not at all, while others can become implemented at disproportionally high cost (Böhringer et al., 2009). Also, efficiency-improving standards suffer from rebound effects as they reduce the marginal cost of transportation (Small and Van Dender, 2007). Finally, to set non-market policies efficiently the regulator needs to draw on reliable techno-economic information.

However, carbon pricing is not a panacea and non-market policies have an important role to play. Where market or government imperfections arise in addition to the basic climate externality– e.g. knowledge spillovers in research and development of low-carbon fuels and vehicles (Jaffe et al., 2005), or lack of policy credibility (Brunner et al., 2010a)–carbon pricing cannot achieve optimal outcomes and complementary standards have an important role to play (Fischer and Newell, 2008). The basic reason is that the number of policy objectives (e.g. internalization of externalities) needs to be matched by the number of policy instruments (Knudson, 2009; Tinbergen, 1952). In many cases a single policy instrument cannot be specified so as to optimally address each of several market failures. This also implies that introduction of market-based instruments will require checking the configuration of standards to ensure that the portfolio of policy instruments properly addresses the ensemble of market- and government failures (Fischer and Newell, 2008).

Given the presently heavy reliance on non-market road transport policies in the European Union, the United States and other world regions (Creutzig et al., 2010a), market-based instruments can be regarded as tools that close the policy space by systematically setting an incentive for harnessing all available abatement options. But there are also less optimistic views of applying market-based instruments in the road transport sector. We examine these in the following section.

2.1 Arguments against market-based regulation

Adverse interaction with existing fuel taxes

Paltsev et al. (2004) and Abrell (2009) argue that in presence of high existing road transport fuel taxes–especially in Europe–further fuel tax increases due to carbon pricing are not expedient from an economic perspective. In Germany, aggregate gasoline taxes (mineral oil tax plus VAT) amounted to 0.85€/liter (2.59$/gal) on average in 2009 (MWV 2010). This corresponds to 367€ (455$) per ton of CO_2 contained in gasoline.[1]

However, governments need to raise revenue to finance public goods (including road infrastructure). Clearly, this raises politically sensitive issues about the proper role of the state and the distribution of the fiscal burden across sectors and social groups. In addition, road transport generates several negative externalities that can be addressed by Pigovian fuel taxation. Specification of the optimal level tax level thus requires an assessment of negative externalities such as noise, accidents, congestion, energy security, and possibly even the less tangible cost of geopolitical conflicts related to energy security including the Middle East (Parry et al., 2007). The monetary evaluation of these externalities necessarily involves normative elements and raises political questions that cannot be fully resolved by scientific inquiry, making specification of optimal fuel tax levels contested. Conceptually, if externalities are not correlated with each other the

optimal fuel tax is equal to the sum of marginal costs of the externalities, and a carbon tax would simply be added to the aggregate Pigovian tax (Newbery, 1992).

Hence, the aggregate optimal transport fuel tax results from combining fiscal and Pigovian fuel tax elements (Parry and Small, 2005). Whether a price on carbon should be added on top of the pre-existing tax level in a specific country to yield the optimal level of fuel taxation is an empirical question involving contested evaluations. Some analysts find that present European Union fuel tax levels are not justified by transport externalities and general taxation requirements (e.g. Paltsev et al., 2004; Parry and Small, 2005) while others consider EU fuel taxes as too low (Sterner, 2007; Proost et al., 2009). In the United States, fuel taxes are much lower than in Europe at around 0.08€/liter (0.24$/gal) (EIA 2010) and there is agreement that this level is not overly high (Paltsev et al., 2004), with some analysts arguing that US fuel taxes should be raised (Parry and Small, 2005). This paper assumes that governments must view current taxes to be optimal, otherwise they would have changed them (Newbery, 1992). Where carbon taxes are not already implemented, a price on carbon would add to the current fuel tax.

Redundancy and lack of impact

With ambitious non-market road transport regulation in place in several world regions it is sometimes argued that market-based policies may be redundant in achieving emission reduction targets (Kågesson, 2008). Indeed, our analysis of emission reductions from standards in the European Union and United States in Section 5.3 shows that substantial reduction can be expected. However, with incomplete information there may be unanticipated abatement potentials that are not captured by standards but would be induced by carbon pricing. More importantly, even a combination of standards will likely fail to incentivize *all* available abatement options, in particular

demand side reductions. This is illustrated in Figure 2. Based on data from CE Delft (Blom et al., 2007) it displays an aggregate marginal abatement cost curve (MACC) for the EU road transport sector and its decomposition into cost effective technical (vehicle efficiency and fuel switching options) and behavioral responses to carbon pricing. Even if standards induced all technical abatement options the demand side MAC is still elastic with respect to carbon pricing.

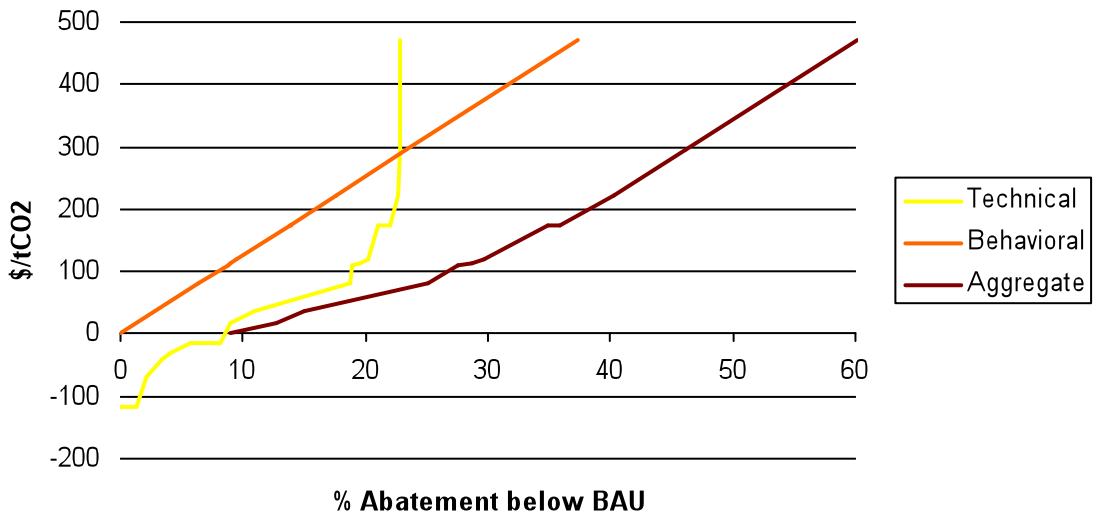


Figure 2: CE Delft year 2020 marginal abatement cost curve for the EU road transport sector and its disaggregation into technical and behavioral cost curves.

It is sometimes argued that the behavioral response to gasoline fuel price increases of 0.035-0.07 €/liter (0.10-0.20$/gal) resulting from a carbon prices of 15-30€ (19-37$) per ton CO_2e are 'too small' to trigger 'substantial' quantities of abatement (Ellerman et al., 2010, p.22). But empirical studies of fuel price elasticities show that on aggregate people and companies do indeed respond to fuel price changes, with short-term elasticities of 0.25 and long-term elasticities of 0.64 (Goodwin et al., 2004; a price elasticity of 0.25 means that 1% fuel price increase lead to 0.25% reduction of

fuel demand). In addition, classifying price increases as 'small' requires a benchmark. One proper benchmark is the price that is required to achieve the environmental benchmark. With a cap-and-trade system in place the amount of emissions is determined by the cap, and the carbon price will adjust automatically to ensure goal attainment (alternatively, a carbon tax can be adjusted to achieve a quantity goal). If 'low' carbon prices suffice to meet the environmental target this is not a sign of climate policy failure but an indication of sufficient low-cost abatement options in the system. Specification of the environmental target is an important but separate question from that of policy instrument choice. A bottom-up rationale on the complementary between market-based on non-market-based instruments in road transport climate regulation is given in the companion paper (Creutzig et al., 2010a).

Dynamic efficiency

Non-marginal technological change will be required to decarbonize the transport sector in the 21st century. Under perfect market assumptions long-term carbon caps or taxes will provide sufficient incentives to foster low-carbon technological change (Edenhofer et al., 2010; Luderer et al., 2010). But perfect markets and governments are not in place and hence the dynamic efficiency of carbon pricing schedules is compromised. It is crucial to note that such imperfections do not remove the basic rationale for market-based policies in the first place. They rather open the policy space for complementary policies–aiming for dynamic efficiency–such as standards, R&D subsidies, and infrastructure investments.

3. Taxes versus cap-and-trade

In a simple framework carbon taxes and cap-and-trade are equivalent instruments. The theoretical literature has discussed asymmetries arising under uncertainty (Hepburn, 2006; Weitzman, 1974) or considerations of supply side dynamics (Kalkuhl and Edenhofer, 2010; Sinn, 2008). Section 3.1 reviews arguments that would favor taxes over trading for road transportation climate policy. The arguments draw on considerations of carbon leakage and transaction costs. Section 3.2 then outlines the argument that cap-and-trade has advantages over taxation under specific but plausible conditions.

3.1 Arguments favoring taxes

In the EU context, including the growing transport sector with its relatively steep abatement cost curve into the EU ETS is suspected to prompt EU allowance (EUA) prices to rise, thereby causing carbon leakage in trade-exposed sectors already covered by the EU ETS (Blom et al., 2007; Holmgren et al., 2006; Kampmann et al., 2008; Kågesson, 2008). A road transport carbon tax would avoid this detrimental general equilibrium effect as it will have no impact on the EUA price.

It is useful to explicate the conditions that need to be met for rendering this argument into a valid public policy concern:

1. The allowance price change induced by road transport inclusion is significant.
2. The carbon price elasticity of leakage is significant, i.e. an increasing allowance price leads to substantial leakage effects. These rates are largely unknown and methodically difficult to determine.
3. No policy instrument exists which could mitigate carbon leakage risk.

4. The welfare loss from carbon leakage is larger than the efficiency gain from harmonizing marginal abatement costs, and a transport carbon tax better balances domestic efficiency and carbon leakage concerns.

This paper only addresses the first concern over an increasing allowance price in the European case (Section 5). We find that for relevant EU climate policy configurations an EUA price increase from road transport integration to the EU ETS is not relevant.

Another argument is that transaction costs of road transport inclusion will be very high, in particular when final consumers are the point of regulation (Ecofys, 2006). However, upstream coverage will contain transaction costs and should not exceed those of current EU ETS facilities, where they are not found to be prohibitive (Ellerman et al., 2010, pp. 245; see also Section 4). Also, monitoring, reporting and verification (MRV) are required for both carbon taxation and cap-and-trade, and the related transaction costs are identical. An asymmetry arises only from the costs of establishing a well-functioning carbon market which will be lower where such a system is already in place (e.g. the EU ETS).

3.2 Arguments favoring cap-and-trade

Three observations motivate the argument of this subsection: (1) marginal abatement costs are uncertain, (2) policymakers prefer quantitative emission targets and (3) sometimes implement cap-and-trade in other sectors of the economy. To illustrate uncertainty over marginal abatement cost curves (MACCs), Figure 3 displays MACC estimates from several models for the European road transport sector in 2020. The differences are striking: at a carbon price of 50$/t$CO_2$e, abatement estimates differ by a factor of ten from 2% (Enerdata-POLES) to 20% (CE Delft) of business-as-usual emissions.

On the global level, preference for quantity objectives is documented by the design of the Kyoto Protocol and more recently the 2°C objective enshrined in the Copenhagen Accord (UNFCCC, 2009) which implies a cumulative carbon budget (Meinshausen et al., 2009; WBGU, 2009). Regionally, the European Union has adopted legislation to reduce emissions by 20% relative to 2005 by 2020. The United States envisage 17% emission reductions below 2005 levels by 2020. The announcements by China and India to reduce carbon intensity of GDP by 40-45% and 20-25% below year 2005 levels by 2020 are also based on emission quantities rather prices.

When a fixed carbon tax is used to manage a carbon budget and MACCs turn out to be higher than expected, there will be a shortfall in abatement and the policy objective is missed. Vice versa, if the marginal abatement cost curve turns out to be flatter than expected, the abatement objective will be exceeded.

Clearly, if the tax rate can be adjusted over time, the policymaker can ensure that a cumulative quantity target is achieved. But repeated adjustment of carbon taxes will likely involve delays, transaction costs, and political controversies. To avoid policy failure of carbon taxation in presence of uncertainty, the regulator can impement international flexibility mechanisms for compliance. For example, the EU climate package enables governments to use CDM credits for compliance with up to 3% of their year 2020 EU-emission objectives in non-ETS sectors. In addition, EU countries can use statistical transfers of non-ETS sector reductions to comply with their reduction burdens in non-ETS sectors, essentially enabling government level emission trading (EC, 2009a). However, if the price of CDM credits or statistical transfers deviates from the carbon tax, this indicates that the policy configuration has been inefficient. In an economy-wide cap-and-trade system, by contrast, the cap will ensure compliance with the policy objective, and trading will

result in a uniform allowance price across all sectors. Hence, abatement is allocated in the most cost effective manner.

With uncertainty over abatement costs, and simultaneous application of a fixed carbon tax in the road transport sector and cap-and-trade in other sectors will almost certainly lead to inefficiency as the tax and allowance price will diverge. When road transport fuels are generated in diverse fuel chains (e.g. crude oil refining, biofuel refining, power generation) such asymmetric carbon prices also imply intra-sector distortions, as transport technologies and modes will face different carbon prices (Bühler et al., 2009). By contrast, an economy-wide cap-and-trade system automatically harmonizes sector carbon prices without need for adjustments by the regulator.

The relevance of this argument clearly depends on the scale of the potential policy failure and inefficiency. If the errors in policy-making turn out to be small, and minor failures in achieving quantity targets can be tolerated or mitigated by using flexible mechanisms, the asymmetry between tax and trading will be weak.

Illustrating the potential order of magnitude of welfare losses from sectorally diverging marginal abatement costs, Böhringer et al. (2009) review three model-based analyses of the recent EU climate package. They find that asymmetric marginal abatement costs in EU ETS and non-ETS sectors as implied by the EU climate package raise year 2020 climate policy costs by 0.25-0.6% in terms of total welfare, or 25-30% above the cost of the efficient policy.

To sum up, cap-and-trade is preferable because it ensures the attainment of quantitative policy objectives and features automatic dynamic harmonization of marginal abatement costs across all abatement options.

4. Cap-and-trade design

Practical implementation of cap-and-trade for any sector requires specification of a number of design elements (Brunner et al., 2010b). The choice of the point of regulation for road transport cap-and-trade has received the most attention in the debate (for a list of relevant publications, see Creutzig et al., 2010b). We revisit and extend this debate beyond the traditional gasoline and diesel fuel chains by also considering electricity, natural gas, hydrogen and biofuels (Section 4.1). Section 4.2 briefly discusses the design of the cap, the allocation of allowance value, and regional flexibility with regard to the road transport sector.

4.1 Point of regulation

The point of regulation specifies where in the transport fuel supply chain emissions are monitored and emission allowances are delivered to the regulator. Commodity chains can be characterized by up-, mid- and downstream processes and actors. For road transport fuels we distinguish the production of feedstocks, fuel production (e.g. refining, power generation, hydrogen production), distribution and storage, and vehicle fuel consumption. Feedstock production is the most 'upstream' and fuel consumption the most 'downstream' level in the product chain, with the remaining stages ranging in between (see Figure 3).

Some (or parts) of fuel chains feature strict proportionality between the energy carrier and ('embedded') greenhouse gas emissions: The amount of CO_2 emissions that will ultimately be released from burning gasoline or diesel produced from one barrel of crude oil can be easily calculated. By contrast, where fuel production (at biorefineries, power plants, or hydrogen plants) uses heterogeneous primary energy inputs with different emission factors (coal, gas, oil, renewables, different biomass stocks) to produce a homogenous output (electricity, hydrogen,

biofuels), only average emission values of the final fuel can be determined using system life-cycle analysis (Creutzig et al., 2010a).

This has two consequences for determining the optimal point of regulation. Strict proportionality of downstream fuel consumption to life-cycle GHG emission implies that any point of regulation can be chosen. However, homogenous final fuels from diverse upstream feedstocks require coverage to be sufficiently far upstream to ensure there is an incentive for switching between primary energy carriers with different emission factors.

Another important aspect is that in competitive markets the costs of surrendering an allowance upstream (e.g. at the refinery) will be factored into the fuel price and shifted downstream. In Germany, for example, fuel taxes are collected at tax warehouses but their burden is shifted to consumers.

Three principles govern the choice of the most effective and efficient point of regulation:

1. All fuel chain emissions should be covered and double counting excluded (effectiveness)
2. All emission reduction options in the sector should be incentivized (efficiency)
3. Transaction costs should be minimized by choosing the point in the fuel chain where the number regulated entities is minimal, where costs of monitoring and compliance are lowest, or where proper administrative structures are already in place

With three principles, four potential points of regulation (feedstock production, fuel production, fuel storage and distribution, final consumption), and five fuel chains a comprehensive discussion needs to cover 60 facets. This is clearly beyond the scope of this paper, and we restrict the discussion to major issues in each fuel chain. Figure 3 provides an overview.

The fuel chains of gasoline, diesel and natural gas exhibit structural similarity. CO_2

emissions per unit energy are proportional throughout the fuel chain, and upstream process emissions e.g. in tar sand processing or oil refining may be covered separately. The major abatement options are switching away from carbon intensive feedstocks (e.g. tar sands) and avoiding combustion of the final fuel altogether. Upstream regulation would require tracking of inputs to products that are not eventually combusted (e.g. lubricants) to ensure they are not burdened with the allowance price (Hargrave, 2000). Effectiveness and efficiency considerations enable regulation at any point in the fuel chain as long as upstream process emissions are covered separately, thus transaction cost considerations will be the decisive factor. Since a detailed analysis of the relative transaction costs of the potential points of regulation is not available and beyond the scope of this study, only the downstream level of vehicles is excluded from the set of recommendable points of regulation as it would literally involve millions of actors. All other points of regulation are generally suitable for effective and efficient cap-and-trade inclusion. For fuels imported from regions that lack comparable carbon pricing systems, the proper point of regulation is at the import of the fuel.

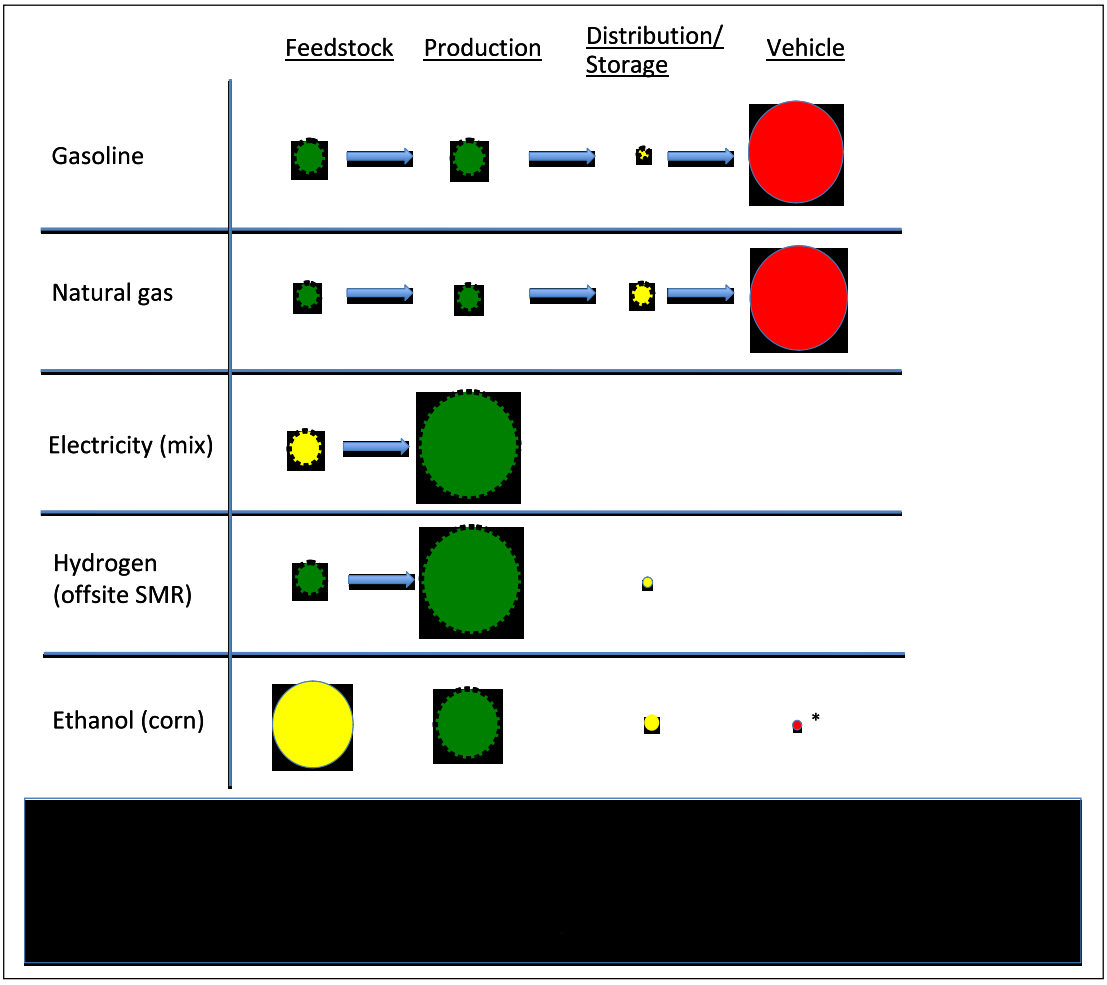


Figure 3: Optimal point of regulation for different transport fuel chains. Sources (data refer to the United States): CARB (2009), Hargrave (2000), NREL (2010), Stavins (2007).

Upstream coverage of fossil-based road transport fuels e.g. at the level of fuel refining is not only widely recommended in the literature (see Kampmann et al., 2008 for a review), but all legislative proposals for cap-and-trade coverage of gasoline and diesel envisage inclusion of emissions at the level of fuel production (ACESA, 2009; Australian Government 2008; APA, 2010; California, 2009;). In the EU ETS, refinery process emissions are already covered (EC, 2003). Coverage at the feedstock production level–i.e. crude, natural gas and coal production–is considered an elegant approach which would enable a comprehensive economy-wide trading system at low administrative costs (Stavins, 2007). Alternatively, the distribution level (e.g. gas distributors, fuel tax warehouses) has been suggested as point of regulation as pre-existing fuel taxation administration structures may be harnessed to contain transaction costs (Bergmann et al., 2005; California, 2009).

The hydrogen and electricity fuel chains also share crucial characteristics. Both involve a homogenous final energy product (electricity and hydrogen) that can be created from a wide range of feedstocks with different GHG emission factors (coal, gas, oil, renewables). Hence, switching to low-carbon primary energy inputs is only incentivized if the point of regulation is sufficiently far upstream at the level of feedstock or the inputs to fuel production. Up-stream regulation incentivizes agents endowed with relatively more options for emission reduction compare to agents at lower stages of a value chain. This implies that up-stream regulation is more cost-effective than down-stream regulation. For electricity and hydrogen imported from regions that lack comparable carbon pricing systems, the proper point of regulation is at the import of the product with average emission factors of fuel production systems in the country of origin have to be applied as the best proxy for accurate accounting.

Biofuels represent the most significant challenge for inclusion to cap-and-trade due to the substantial technical greenhouse gas accounting difficulties (Creutzig and Kammen, 2009; Creutzig et al., 2010a). Emissions associated with biomass production will differ across crops, regions, farmers and even fields. Accurate monitoring of emissions at the farmer and field level would involve significant transaction costs making this approach infeasible. In addition, even if such a system was put in place in one region but not on a global scale, *indirect* global effects of domestic biomass production still arise as world agrarian market prices will be affected by domestic production inducing changes in global emission levels that depend on market dynamics and land-use and land-use change patterns. Hence, life-cycle accounting differentiated by crops and regions at the input level of biofuel production facilities appears as the second best point of regulation. In analogy to electricity and hydrogen, this would enable switching across more or less GHG-intensive biomass feedstocks which would not be possible with regulation of homogenous biofuels (e.g. ethanol) further downstream. Imported biofuels from regions without a comparable carbon pricing system have to be accounted by using average values from life-cycle analyses.

Another proposal not investigated here includes vehicle manufacturers into cap-and-trade system by attributing their vehicle sales with expected lifetime emissions and requiring delivery of allowances from the manufacturer at the time of vehicle sales - effectively frontloading allowance expenditures for fuels for the consumer (Winkelman et al., 2000). This approach suffers from two fundamental problems. First, it is inefficient because it sets no incentive to adjust driving behavior and fuel production. Second, attributing lifetime emissions to vehicles requires cumbersome definition of uniform emission factors for fuels and cars. Policy design is further complicated by the need of multi-year trading periods to enable car manufacturers surrendering allowances for vehicle emissions several years ahead.

In summary, there is some flexibility in choosing the appropriate point of regulation without compromising effectiveness and efficiency if (1) coverage is comprehensive and avoids double counting, (2) all mitigation options are incentivized, and (3) transaction costs remain low. The feedstock and fuel production levels are recommendable points of regulation for all of the considered fuel chains, except for biomass where only refineries and life-cycle accounting are recommended due to prohibitive transaction costs at the farming level. While it is theoretically possible to determine different points of regulation for different economic sectors (Hargrave, 2000), consistency is necessary for avoiding loopholes and double-pricing.

4.2 Other design features

Two aspects are essential when determining the cap of an ETS that covers road transportation. First, the cap needs to be in line with regional and global emission reduction targets. Second, if a cap-and-trade system covers only part of an economy's emissions, the cap needs to be set so as to ensure an efficient effort-sharing between ETS and non-ETS sectors (Böhringer et al., 2009). As efficiency implies harmonized marginal abatement costs across sectors, adding a non-ETS sector to an ETS should actually not impact allowance prices.

Allocation of allowance value has an efficiency and distributional dimension. Perverse incentives from free allocation–e.g. when future free allocation is based upon current emission levels–need to be avoided. Auctioning is widely preferred by economists as this method does not suffer from such shortcomings (Hepburn et al. 2006). Free allocation is sometimes used as a subsidy to protect trade-and carbon-price exposed sectors (such as steel and aluminum) from international competitors not facing comparable constraints (EC, 2010). This aspect is not relevant for road transportation as the final economic activity is not subject to international trade.

In competitive markets companies will pass on the opportunity costs of using allowances to final consumers irrespective of the allocation method (Sijm et al., 2006). If companies receive allowances for free they increase their revenue by increasing product prices without having to pay for allowances, realizing so-called windfalls profits. This effect would occur if e.g. transport fuel refineries and importers were included to a cap-and-trade system and received allowances for free. Fuel prices would rise and generate additional revenues for these actors. Auctioning of allowances eliminates windfall profits, and the revenue can be used for a variety of purposes, including ensuring a progressive distribution of the policy burden by compensating consumers accordingly (Burtraw et al., 2009).

Regional flexibility is provided by linking regional cap-and-trade systems or by enabling access to credits e.g. from the Clean Development Mechanism (CDM) (Tuerk et al., 2009). Linking promises efficiency gains if permit prices differ across regions and harmonization of allowance prices across cap-and-trade systems eliminates industrial competitiveness concerns by 'levelling the carbon playing field' (Flachsland et al., 2009). When linking to crediting schemes it is paramount to ensure additionality. This means that emissions need to be reduced below business-as-usual levels, i.e. credits shall not be issued to rewards emission reductions that would occur anyways (Schneider, 2007). Linking cap-and-trade systems of major automobile markets such as the United States and Europe would ensure harmonized carbon prices across these markets, which facilitates research, development and deployment planning of international firms.

5. Economic impacts: the European case

5.1 Concepts, data and scenarios

Marginal abatement cost curves are a standard tool for analyzing price and quantity effects in carbon markets and are widely used to analyze the integration of regional trading systems (Anger, 2008; Criqui et al., 1999; Ellerman and Decaux, 1998; Stankeviciute et al., 2008). The basic concepts for analyzing regional links or integration of sectors are identical. Figure 4 displays four marginal abatement cost curves for the European road transport sector and one aggregate MACC for the EU ETS sectors.

Marginal abatement cost curves can be derived in several ways which is reflected in the differences across models (Clapp et al., 2010). Important choices concern the model structure (e.g. top-down versus bottom-up, scope of considered technologies and behavioral reactions), baseline assumptions (e.g. energy prices, economic growth, technological innovation) and policy assumptions regarding the baseline.

Among the MACCs applied in the analysis below, only the CE Delft road transport curve explicitly includes demand side responses while McKinsey and AIM/Enduse do not include this option. Including behavioral responses into the other curves would flatten all of them (see Figure 2). Also, none of the transport MACCs takes the 2009 EU climate package into account, which would unambiguously shift curves downwards (see Figure 10 and the discussion in Section 5.3). Finally, none of the models takes the world economic crisis into account. This would also shift marginal cost curves downwards, as year 2020 baseline emission levels are reduced and a lower price incentive is required to yield a given level of emissions.

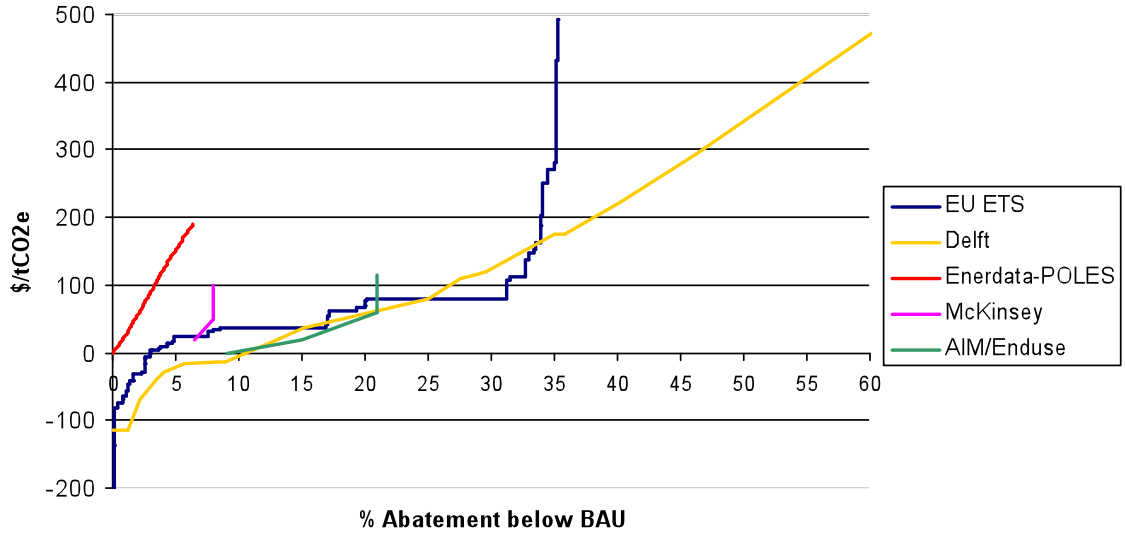


Figure 4: Comparison of marginal abatement cost curves for year 2020 EU road transport sector from CE Delft (Blom et al., 2007), Enerdata-POLES (Enerdata, 2010), McKinsey and AIM/Enduse (Clapp et al., 2009) and an aggregate EU ETS curve (Blom et al., 2007).

When modeling road transport inclusion to the EU ETS, the MACCs from Figure 4 need to be modified to reflect the EU ETS link to the CDM (EC, 2004). This regional flexibility can be modeled by adding the permitted volumes and prices of credits to the schedule of available abatement options (Figure 5).

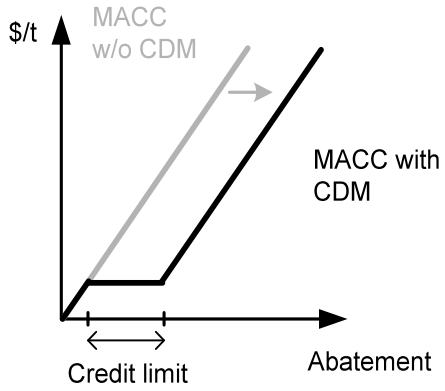


Figure 5: Including limited international credit supply to a marginal abatement cost curve. Credits

enable access to additional abatement options in other countries, and the price of this abatement option is set by the world market. The formulation here assumes that demand for credits does not impact the world market price, thus the credit abatement 'lever' is horizontal.

The EU has specified a complicated set of rules determining the quantity of credits available in the EU ETS in the 2013-2020 trading period (EC, 2009b). Our estimate for credit use is the mean of the average annual estimates summarized in Capoor and Ambrosi (2009, p.8), which amounts to 150Mt per year. A CDM world market price of 30$/t is assumed. As a new sector, road transport would increase the total amount of credits available in the EU ETS. The reformed EU ETS Directive suggests that road transport would increase the amount of available credits in the EU ETS by 4.5% of year 2020 road emissions (EC, 2009b, Article 11a). In the scenario where EU emission reductions are enhanced from 20% to 30% relative to 1990, we assume that 50% of the additional abatement effort can be covered by credits.

Figure 6 illustrates how MACCs enable the analysis of price and quantity effects of adding sectors to an existing cap-and-trade system. The horizontal axis depicts the total abatement required by both sectors. In our example, the section left of Q_{set} represents the abatement target for the ETS already in place, while the section to the right of Q_{set} denotes the abatement target for the road transport sector to be included. The ETS pre-link allowance price P_{ETS} is determined by the intersection of the EU ETS curve and the policy target (Q_{set}), while the transport sector pre-integration MAC is given by P_{trans}. The optimal allocation of abatement Q^* and the corresponding optimal allowance price level P^* result at the intersection of the MACCs as indicated in the right hand panel. The aggregate efficiency gain is indicated by the shaded area.

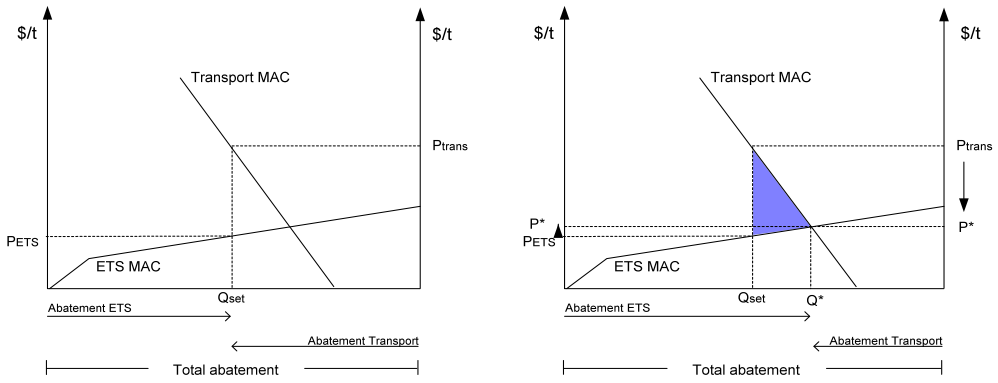


Figure 6. Pre- and post-integration carbon market equilibria and efficiency gains from including road transport. The left figure indicates asymmetric marginal abatement costs prior to road transport inclusion. The right figure indicates the direction of price changes after integration, with the shaded area denoting the efficiency gain from trade.

The assumptions on abatement targets in the default policy scenario are based on the EU-wide GHG reduction target of 20% below 1990 levels by 2020 (EC, 2009a, b). The European Commission (EC, 2008) reports that EU policymakers adopted an implicit sector emission reduction burden-sharing where the EU ETS sectors need to reduce their year 2020 emissions by 21% below 2005 levels. The transport sector is supposed to reduce emissions 7% below its 2005 level by 2020 (EC, 2008). The Commission claims that these are the efficient burden-sharing levels as determined in modeling exercises, i.e. marginal abatement costs in these calculations are supposed to be harmonized across sectors. Table 1 summarizes historic emissions, future projections, sector caps and abatement targets for the EU ETS and the considered road transport MACCs.

Unit: Mt CO_2e	EU ETS (Delft)	Road Transport			
		Delft	Enerdata-POLES	McKinsey	AIM/ Enduse
2005 emissions	2014	895	895	895	895
2020 BAU emissions	2363	1116	893	1000	1100
2020 cap in 20% scenario	1591	832	832	832	832
2020 abatement below BAU, absolute	771	284	61	168	268
2020 abatement below BAU	**33%**	**25%**	**7%**	**17%**	**24%**

Table 1: 2005 emissions from EU ETS and road transport sectors, baseline emission projections from different models, sector policy targets under the 20% EU-wide reduction target, and corresponding abatement targets for the EU ETS and transport sectors (in $MtCO_2e$). Sources: Historical year 2005 emissions EEA (2010); year 2020 BAU projections same as Figure 4.

A scenario with 30% reduction below year 1990 emission is investigated in addition to the 20% default policy case (EC, 2010). For this enhanced EU effort we assume that EU ETS and road transport uniformly increase their abatement by 50% above the effort required compared to the default scenario. Thus, modified ETS and road transport reduction targets are 31.5% and 10.5% below year 2005 emission levels, respectively. In a third policy scenario, we investigate the impact of the 20% default policy scenario while excluding the link to crediting schemes.

5.2 Results

Figure 7 displays the CE Delft and Enerdata-POLES results for the 20% policy default case (see Appendix Ia-c for all scenarios and models). Figure 8 summarizes the price changes in the EU ETS and the road transport sector, and Figure 9 shows how abatement quantities shift between sectors.

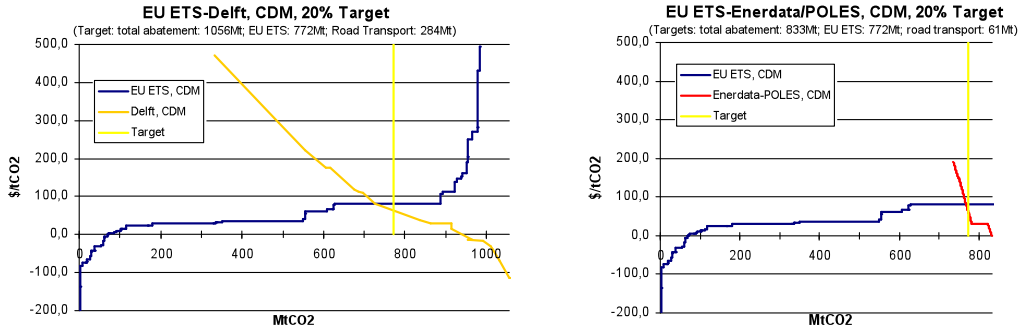


Figure 7: Economic impacts of integrating EU road transport into the EU ETS by 2020 using CE Delft (left) and Enerdata-POLES (right) road transport MACCs. Pre-integration prices and quantities are determined by the intersection of the MACCs with the vertical line which indicates sector abatement targets. Post-integration price and quantity equilibrium results where the MACCs intersect.

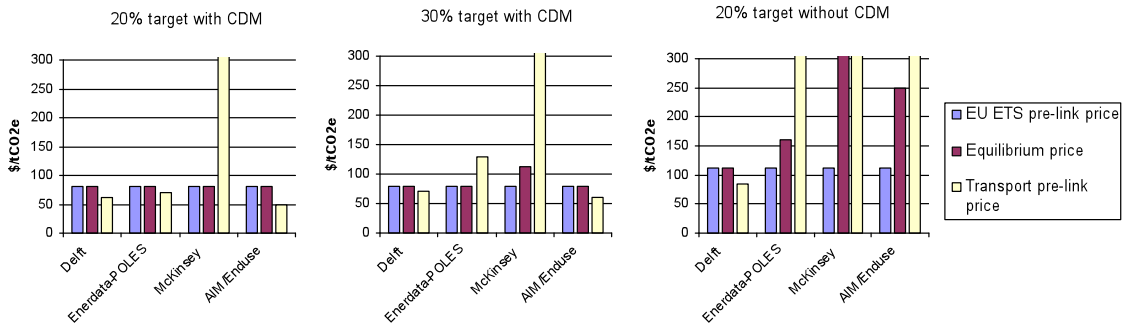


Figure 8: Price effects of EU road transport integration into the EU ETS in 2020 for three policy scenarios and four models. The figure displays pre- and post-integration marginal abatement costs in the EU ETS and transport sector. Bars exceeding the scale indicate that the abatement target cannot be achieved because the model lacks sufficient abatement options.

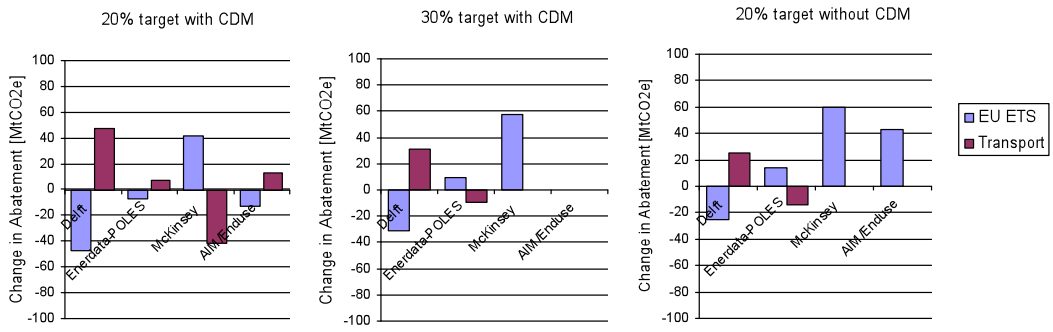


Figure 9: Change in abatement quantities across sectors when including EU road transport into the EU ETS in 2020 for three policy scenarios. Positive values mark increased abatement activity in a sector and vice versa. Where the changes for EU ETS and transport sectors do not cancel out, the quantity objective is not achieved prior to transport integration because models lack sufficient abatement options.

As the perhaps most striking result, in the default 20% policy scenario the EU ETS allowance price remains unchanged for all models (Figure 8). This is in contradiction to previous MACC-based assessments usually concluding that road transport integration to the EU ETS would

raise the EUA price (Blom et al., 2007; COWI, 2007; Hartwig et al., 2008; Holmgren et al., 2006). Integration of road transport would actually reduce the amount of abatement required from EU ETS sectors for all but the McKinsey model (Figure 9).

This result can be explained by the combination of (i) the volume of abatement potentials in road transport as represented by the MACCs, (ii) regional flexibility in meeting part of the abatement target with CDM credits, and (iii) the 7 % road transport reduction target below 2005 levels not representing a very large challenge for EU road transportation given the scope for domestic and foreign abatement.

The pre-integration EUA price of 80$/t for the year 2020 is quite high compared to the 37$/t reported by EC (2008) modeling, or private sector estimates of 37-50$/t reported by Capoor and Ambrosi (2009, p.8). This reflects the rather conservative EU ETS cost curve estimate by CE Delft (see Blom et al., 2007).

In the 30% reduction scenario, the same picture emerges except for the McKinsey cost curve. In this model the constraint becomes so tight that the EUA price needs to rise to incentivize more expensive abatement options in the EU ETS. It is worth noting that the McKinsey model does not take demand side reductions into account. Including this abatement option into the model would flatten and extend the marginal abatement cost curve and would dampen the EUA price increase (see Figure 2).

In this context it is worth taking into account that the economic crisis has eased the conditions for meeting a 30% reduction target (EC, 2010). The MACCs in this analysis would reflect the economic crisis by shifting downwards, thereby dampening impacts on allowance prices.

The third policy scenario (20% reduction target without access to CDM) leads to substantially different outcomes. Except for the CE Delft curve, EU ETS prices rise and the ETS sectors need to deliver additional abatement. Even for the CE Delft case the pre-link EUA price level is higher than in the default scenario because more expensive domestic abatement options need to be harnessed as international emission trading is not available. For the McKinsey model the aggregate target is not feasible because it does not no include sufficient domestic abatement potentials. This scenario illustrates the importance of regional flexibility for containing EUA prices.

Several conclusions can be drawn from this analysis. First, with the EUA price remaining constant in case of road transport inclusion to the EU ETS in the 20% default policy scenario in all models, concerns over carbon leakage from transport inclusion appear less well-founded than is often suggested in the literature.

Second, the relatively moderate sector differences in pre-integration MACs and the correspondingly modest changes in sectoral abatement in case of transport integration in the default policy scenario indicate that EU policymakers perform well in terms of sector burden-sharing. Note, however, that the instruments for the road transport sector are not market-based and hence the abatement options in this sector do not consistently face the shadow price of emissions. Therefore, it can be expected that road transport inclusion would still deliver efficiency gains.

Third, the McKinsey and AIM/Enduse models ignore demand side responses and only represent technical abatement options. Taking behavioral responses into account would lower the transport MAC curves. Therefore EUA price increases for these curves would be lower than indicated here. In a similar vein, taking into account the world economic recession reduces business-as-usual emissions and would work towards reducing EUA price levels and changes in all of the considered policy scenarios.

Finally, this analysis does not include non-price policies as embodied by the recent EU climate policy package (e.g. EC, 2009c). A detailed analysis is beyond the scope of this study. However, estimates of the impact of non-price road transport policies on abatement in the European Union, the United States and California are discussed in the next section.

5.3 Interaction with non-market policies

As noted in Section 2.1, non-market policies will induce abatement even in absence of market-based policies. In the MACC framework this can be represented as a shift in the marginal abatement cost curve as shown in Figure 10. In a cap-and-trade system, standards that trigger abatement options that either cost more than the equilibrium allowance price P^* or that do not respond to an allowance price due to some market failure will have the effect of reducing the equilibrium allowance price to P^s.

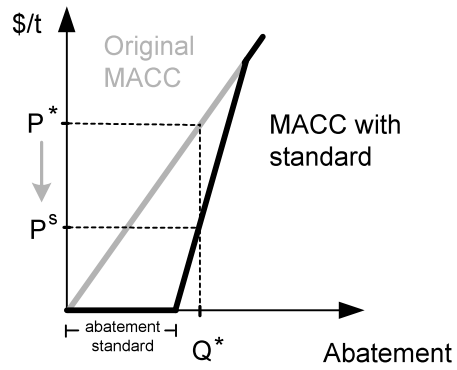


Figure 1: Standards shift the marginal abatement cost curve downwards and can reduce the allowance price in cap-and-trade systems.

Creutzig et al. (2010b [calculation is attached as Appendix II since Creutzig et al. 2010b is forthcoming]) calculate that EU non-market policies such as vehicle emission intensity standards, the Fuel Quality Directive and measures including improved air conditioning and tires will reduce EU road transport emissions in 2020 to around 11% of the 2005 level, despite moderate growth of transport volumes (EC 2009c). This would not only exceed the 7% year 2020 reduction target below 2005 emissions assumed in the default policy scenario above, but also the 10.5% target assumed for the enhanced 30% EU-wide effort. In the United States–assuming the revised US

CAFÉ standards will remain constant from 2016 to 2020–vehicle efficiency standards will induce road transport emissions to drop by 3% relative to 2005 levels in 2020.

What does this mean for the EU ETS integration of the European road transport and the results derived above? As standards have the effect of shifting the road transport MACCs downwards, this unambiguously works towards reducing allowance prices in the integrated trading system. In the same vein, it will work towards reducing the level of abatement required in the EU ETS sectors. Therefore, the analyses in the previous section tends to overestimate the increase of the EUA price when adding road transport to the EU ETS.

6. Conclusions

Well-designed market-based instruments such as carbon taxes and cap-and-trade systems have several advantages over non-market climate policies for the road transport sector. Their merits include the provision of abatement incentives across all available emission reduction options (within and across sectors) at harmonized marginal costs of abatement, the elimination of rebound effects, a level playing field for competing technologies, and lower informational requirements. Therefore, market-based climate policies fill an important policy gap in the current road transport policy portfolio that is dominated by non-market instruments in many regions including the European Union and the United States. Where carbon price signals are ineffective due to market failures, non-market policies continue to play an important complementary role.

Cap-and-trade and carbon taxes are equivalent instruments in a simple analytic framework. However, cap-and-trade is the favorable instrument if marginal abatement costs are uncertain and policymakers prefer quantitative emission targets, or if a cap-and-trade system has already been

implemented in other sectors of the economy. If errors in setting a carbon tax turn out to be small or flexibility mechanisms are implemented to contain the magnitude of error, the asymmetry between tax and trading will be weak.

An upstream point of regulation at the level of feedstock or fuel production (e.g. refineries and power plants) is recommended to ensure effectiveness, efficiency and low transaction costs in presence of diversifying fuel chains. Biofuels exhibit particular challenges due to the difficulty of monitoring emissions from geographically spread biomass production. Auctioning of allowances is preferable to free allocation to ensure efficiency and avoid windfall profits. Well-designed links to other cap-and-trade systems will 'level the carbon playing field' across the linked regions and enhance efficiency. Gains from trade also motivate links to emission crediting schemes.

A comparative analysis of integrating the road transport sector into the EU ETS in 2020 reveals that in the present EU climate policy configuration (20% economy-wide reductions below 2005 levels by 2020) no allowance price changes would result from adding the sector to the EU ETS. This can be explained by the interplay of the volumes of abatement that are available in the road transport sector, regional flexibility exhibited by the access to CDM credits, and the relatively modest emission reduction target for the road transport sector that is envisaged by EU policymakers. Therefore, the widespread concern over carbon leakage from trade-exposed EU ETS sectors in case of rising allowance prices due to road transport inclusion is not confirmed by our results.

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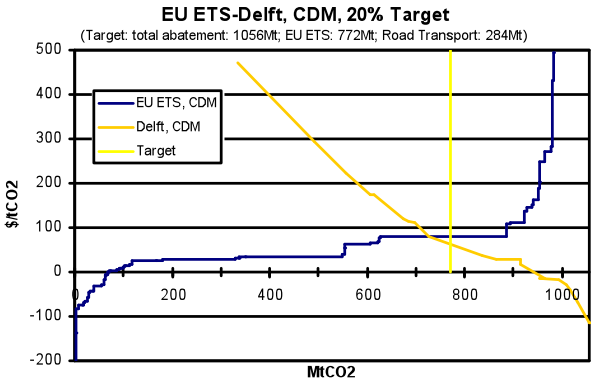
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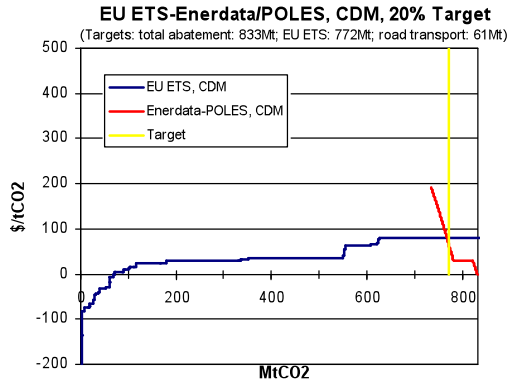
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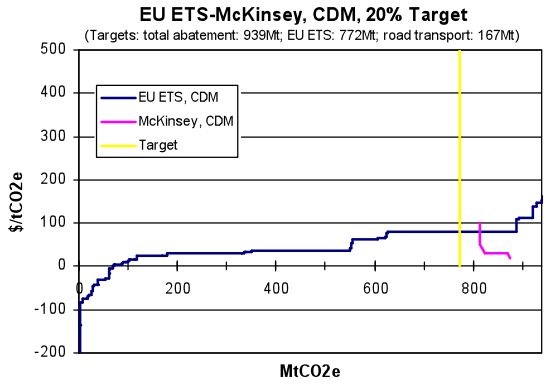
Footnotes

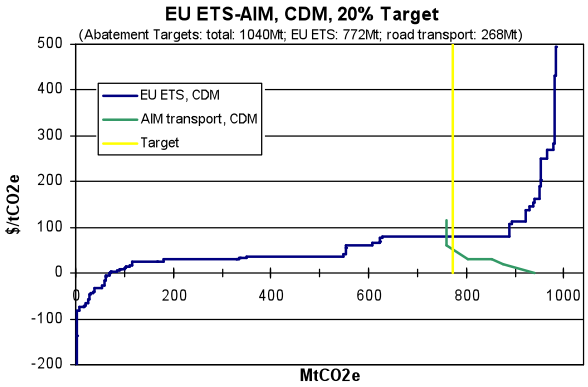
[1] Throughout this paper, the exchange rate from Euro to US$ is 1 to 1.24. Combustion of one liter gasoline results in 2.315 kg CO_2 emissions (Carbon Trust 2008).

Appendix Ia: EU ETS inclusion road transport - 20% default scenario with CDM

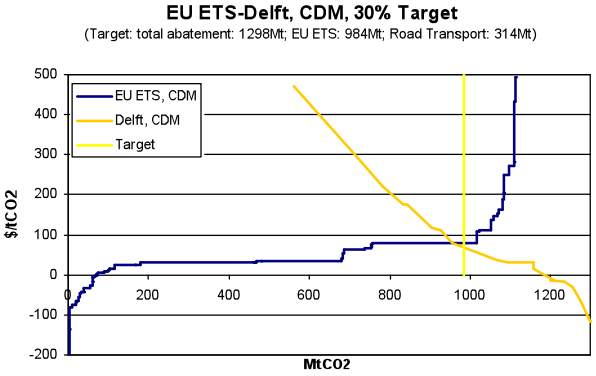


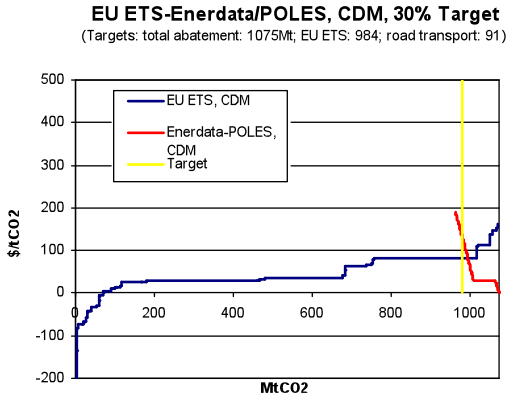


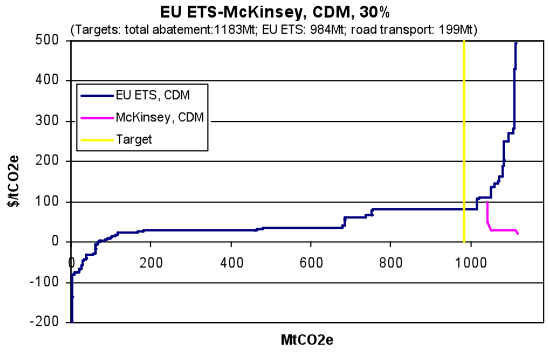


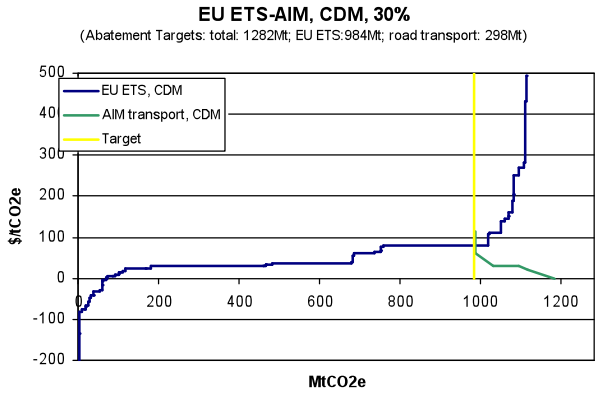

EU ETS-AIM, CDM, 20% Target
(Abatement Targets: total: 1040Mt; EU ETS: 772Mt; road transport: 268Mt)
EU ETS, CDM
AIM transport, CDM
Target
$/tCO2e
MtCO2e
500
400
300
200
100
0
-100
-200
0
200
400
600
800
1000

Appendix Ib: EU ETS inclusion road transport - 30% reduction with CDM

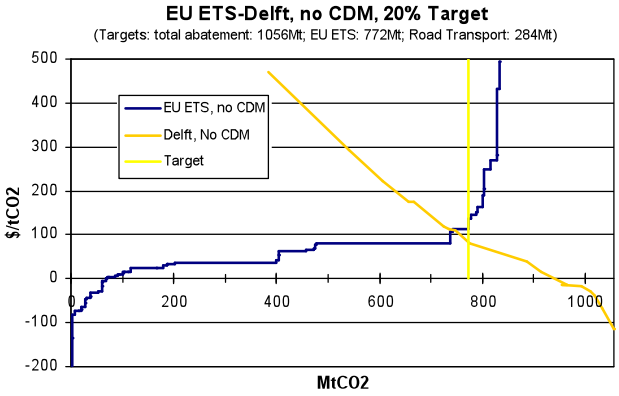


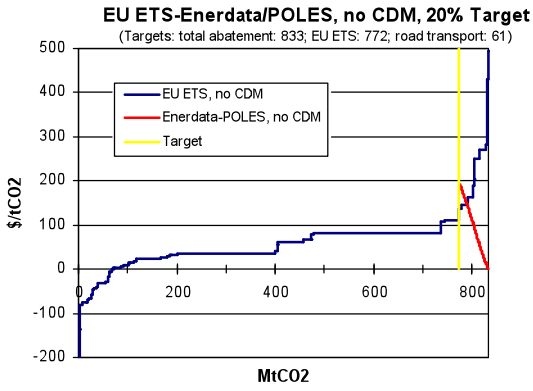


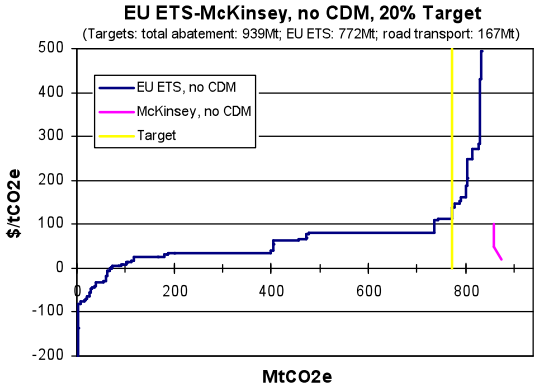


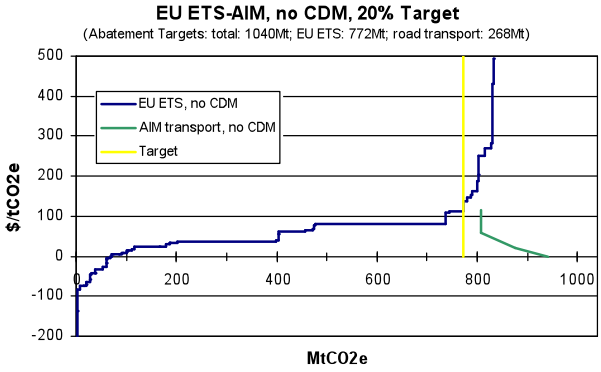


Appendix Ic: EU ETS inclusion road transport - 20% reduction without CDM






EU ETS-McKinsey, no CDM, 20% Target
(Targets: total abatement: 939Mt; EU ETS: 772Mt; road transport: 167Mt)
EU ETS, no CDM
McKinsey, no CDM
Target
$/tCO2e
MtCO2e
500
400
300
200
100
0
-100
-200
0
200
400
600
800


EU ETS-AIM, no CDM, 20% Target
(Abatement Targets: total: 1040Mt; EU ETS: 772Mt; road transport: 268Mt)
EU ETS, no CDM
AIM transport, no CDM
Target
$/tCO2e
MtCO2e
500
400
300
200
100
0
-100
-200
0
200
400
600
800
1000

Appendix II – Calculating the impact of non-price policies

[this Appendeix is only included to submitted paper;,the text is part of a referenced publication which is due for August/September 2010]

II.1 European Union

The current EU regulation of emission intensity of new vehicles dates from April 2009 (EC, 2009c) and, hence, has not been included in previous models of transport inclusion into emission trading. The regulation mandates the average carbon emissions from newly sold vehicles to decrease from 167gCO_2/km in 2005 to 130gCO_2/km in 2015, and to 95gCO_2/km in 2020 (see also chapter 3). This corresponds to 40% reduction in emissions intensity of new vehicles sold by 2020.

How large is the emission reduction in the transport sector in the EU in 2020 given by this and other policies? New vehicles, of course, do not substitute the current car fleet. A good working assumption is a 10% turnover rate every year. The question can be broken down in different parts. What were the average emissions per vehicle in 2005? Data is available for the year 2000, with average emissions per vehicle in 2000 being 186 gCO_2/km (EC 2000). Emission intensity of newly sold vehicles between 2000 and 2005 were relatively constant at around 167 gCO_2/km (An and Sauer, 2007). Assuming a 10% annual turnover rate, the average 2005 fleet average was 178 gCO_2/km.

Average emission intensities for 2020 are more difficult to estimate. Newly sold cars after 2015 will have less than 130 gCO_2/km on average, as the average heads towards the 95gCO_2/km value of 2020. These vintages may constitute around 40% of the overall fleet. Linear interpolation

of fuel economy values between 2015 and 2020 then yields an average fleet intensity of 125 gCO_2/km in 2020.

Additional measures, such as improved air conditioning and tires, but also biofuels are expected to deliver another intensity reduction of 10 gCO_2/km until 2015. To be on the conservative side, we omit the car-related measures. We do include the more specific Fuel Quality Directive COM-2007-18 which requires 6% reduction in CO_2e of transportation fuels from 2010 to 2020 (EC 2009c). At the same time, total road transport demand is projected to rise from 4700 Gpkm in 2005 to 5800 Gpkm, an increase of 24% (EC 2008b). We omit any rebound effects. Taking together, carbon emissions from road transport (not including other transport, such as air traffic) will be reduced by around 11% in 2020. This would even exceed our assumed road transport reduction target of 10.5% in presence of a 30% economy-wide EU abatement target. This result may be overly optimistic for four reasons

1. The extrapolation is linear in annual improvement of fuel economy. However, car manufacturers may choose, according to current regulation, to back-off investments till the 2015 or 2020 deadlines respectively.
2. Car renewal rate is estimated to be around 10%. In recession times, the car renewal rate could be lower. However, total transport volumes would also drop.
3. Rebound effects are omitted here. They can be regarded to be part of the overall uncertaintyin growth of travel demand.

3. The environmental effectiveness of the Fuel Quality Directive COM-2007-18 is not guaranteed due to the current accounting procedures that does not foresee detailed life cycle analysis including indirect land use emissions.

However, even if these caveats reduce overall GHG reduction, current EU regulation seem to guarantee that at least the 7% reduction target (below 2005 levels by 2020) is achieved even without carbon pricing.

II.2 United States

The United States has similarly ambitious targets for fuel economy in relative terms, i.e. taken the currently more inefficient vehicle fleet into account. Including extra measures such as improved air conditioning, tire pressure and biofuels, the revised CAFÉ standard foresees the average fuel efficiency of newly sold vehicles to increase from 221 gCO_2/km in 2005 to 155 gCO_2/km in 2020. For the calculation it is assumed that mandated fuel economy remains constant from 2016 to 2020. With a fleet renewal rate of 10%, and average fuel economy of 245 gCO_2/km in 2005, the average fuel economy in 2020 in the US is then projected to be 186 gCO_2/km, corresponding to a total improvement of 24% relative to 2005. At the same time, US vehicle miles travelled are expected to increase by 27% (EIA 2008). Given this projected development and policies, and omitting rebound effects, overall GHG emission reduction by 2020 in road transport is 3% relative to 2005.