Transportation Research Part D 15 (2010) 235–239

Contents lists available at ScienceDirect

Transportation Research Part D

journal homepage: www.elsevier.com/locate/trd

Notes and comments

Regulating CO_2 emissions of transportation in Europe: A CGE-analysis using market-based instruments

Jan Abrell

Dresden University of Technology, Department of Business and Economics, D-01062 Dresden, Germany

ARTICLE INFO

Keywords:
Transportation
Carbon regulation
Emission trading
Computable general equilibrium

ABSTRACT

This paper analyzes the use of market-based emission regulation instruments to address the carbon dioxide emissions of transportation. Simulations with a static multi-region computable general equilibrium model show that including transportation into the European emission trading system is superior to a closed emission trading system for transportation or a tax-based approach. Furthermore, we show that exempting transportation from emission regulation is the most favorable approach in terms of welfare. This counterintuitive result is due to a large tax-interaction effect caused by high pre-existing fuel taxes in the transport sector.

© 2010 Elsevier Ltd. All rights reserved.

1. Introduction

Around one quarter of the carbon dioxide (CO_2) emissions of the European Union (EU) are caused by the transportation sector. While total greenhouse gas emissions in the EU decreased between 1995 and 2005 by around 1.4%, emissions caused by transportation rose 17.3% during the same period (EUROSTAT, 2007). This trend of transport emissions, which is mainly caused by private road transport, is expected to continue further.

In contrast to emissions of energy and energy-intensive industries, which are regulated under the European Emission Trading System (EU ETS), transport emissions are currently regulated at the member state level. One of the main instruments in use is fuel taxation and, consequently, all European countries are characterized by high gasoline taxes ranging from €0.60/l (Luxembourg) to €1.25/l (Hungary) (Sterner, 2007). The specific carbon emissions of new cars in the EU are regulated from 2012 onwards (European Commission, 2009a). Further possible approaches include imposing further fuel taxes at a European level or including road transport into the EU ETS in a down-, mid-, or upstream manner. Downstream trading, i.e. drivers have to hold emission allowances, is expected to incur high information and transaction costs due to the large number of polluters.[1] Midstream trading, i.e. automobile producers have to hold permits for the lifecycle emissions of the sold vehicles (Albrecht, 2000), faces the problem of deriving the lifecycle emissions based on a representative driving cycle, which is only a rough presentation of owners' driving behavior. Therefore, upstream emissions trading in which producers and importers of transportation fuels are obliged to hold allowances is the most promising option especially since refineries are already part of the EU ETS.

We analyze the welfare implications of using market-based emission regulation to assess the emissions of transportation. Besides the possibility to include transportation into the EU ETS, national or European-wide taxes on transport fuels can be used. Simulations with a static multi-region computable general equilibrium (CGE) model show that the first option is superior to the latter ones. However, the results show that exempting transportation from emission regulation and increasing the

E-mail address: jan.abrell@tu-dresden.de

[1] Raux (2004) argue that information and transaction costs can be minimized by using an electronic system compatible to already existing credit card systems for allowance trade: Furthermore, gas station operators or banks could serve as market intermediaries.

1361-9209/$ - see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.trd.2010.02.002

Table 1
Reduction requirements. Source: European Commission (2009b).

Region	Reduction (% vs Benchmark)	Region	Reduction (% vs Benchmark)
Benelux	16	Spain	10
Denmark	20	Sweden	17
Finland	16	United Kingdom	16
France	14	Western EU	10
Germany	14	Remaining Eastern EU	−15
Italy	13		
Poland	−14	Annex I	5

reduction burden of sectors regulated under EU ETS is superior to transportation under emissions trading. This is due to the large pre-existing fuel taxes in the transport sector which cause a welfare reducing tax-interaction effect.

Few studies have analyzed carbon constraints for road transportation in a general equilibrium framework. Among them, Paltsev et al. (2005a) is most closely to our work. Using a multi-region CGE model, they find that exempting transportation from carbon restrictions results in welfare gains in Europe but losses in the US. The result is based on the observation that pre-existing taxes in transport fuels are higher in Europe than in the US. In contrast to their work, the presented approach analyzes the European carbon market in a finer spatial disaggregation and explicitly deals with separated carbon markets under the EU ETS.

2. Model

For the simulations, a static multi-region CGE model is employed. The presented model is developed to analyze the European carbon market. Therefore, European countries are included in a disaggregated manner while non-European countries are aggregated to Annex I and non-Annex I countries (Table 1). As carbon emissions are related to fossil fuel use, energy production is represented in detail (coal, crude oil, natural gas, electricity, refined oil products). The model includes industrial and private transport as well as manufacture of transport equipment. Non-electricity EU ETS sectors are aggregated to energy-intensive industries according to the Annex of the European emission trading directive (European Commission, 2003). Further industries are combined to agriculture as well as other industries and services. Representative households' are endowed with capital, labor and natural resources.

The different sectors' production and final consumption are modeled using nested Constant Elasticity of Substitution (CES) functions. The nesting structure of the functions and the respective substitution elasticities are given in Fig. 1.[2] Except for the extractive industries (coal, natural gas, and crude oil), all sectors have the same production structure. For all sectors and consumers fossil fuel inputs are associated with CO_2 emissions. Consumers' demand is modeled by regional representative households, which earn income by inelastically supplying primary factors to the domestic market. While capital and labor are fully mobile across sectors but not across regions, natural resources are sector specific i.e. immobile across sectors and regions. Private transport is represented as a composite of purchased and own provided transport which consists of refined oil consumption as transport fuel and other costs in the form of car and other transport related purchase such as repair and assurance services.

Governments finance commodity demands and transfers to private households by tax revenues. Government demand is modeled using a Leontief function and the balance of payment deficit is assumed to be fixed at the benchmark level. Domestic and imported commodities as well as imported commodities from different regions are imperfect substitutes (Armington, 1969). Furthermore, importing commodities are associated with transport margins which are supplied by industrial transport sectors. Investment demand is modeled using a Keynesian closure, i.e. the marginal propensity to save is held constant at the benchmark level. The investment commodity is a Leontief composite.

For the parameterization of the baseline of the model, the Global Trade Analysis Project (GTAP) database of Version 6 is used (Dimaranan, 2006). The physical energy flows given in GTAP together with emission factors (Intergovernmental Panel on Climate Change, 2006), and historical emission data for the year 2001 (World Resource Institute, 2008) are used to determine CO_2 emissions. As GTAP does not offer a detailed representation of household transport, the method developed by Paltsev et al. (2004) and data of the European Budget Survey (EUROSTAT, 1999) are employed to include household transportation.

3. Policy scenarios and results

The scenarios are designed to analyze a European-wide carbon tax increase in the transport sector as well as the implication of transport as part of the EU ETS. In all scenarios European regions are obliged to fulfill nominal emission targets as given by the effort sharing agreement (Table 1). Remaining Annex I countries are assumed to reduce their emissions by 5%.

[2] Sensitivity analysis has been carried out for the elasticities in the private transport module. Although, the results vary in absolute magnitude, the ranking of the different regulation approaches is not affected.

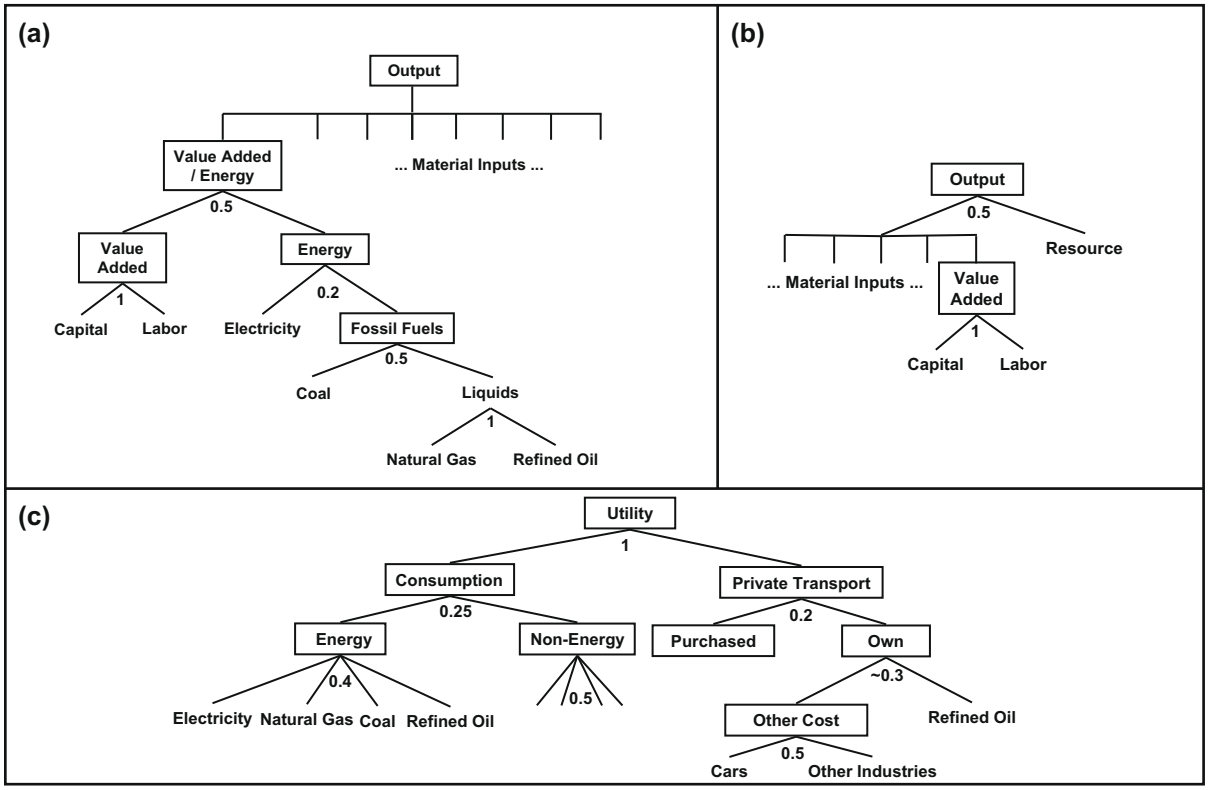

Fig. 1. CES functions for (a) non-extractive, (b) extractive industries, (c) final consumers. Source: numbers indicate the substitution elasticities (Paltsev et al., 2005b; Burniuax and Truong, 2002). The substitution elasticity between refined oil and other cost in own provided transport is calibrated to a price elasticity of gasoline demand of 0.3 (Graham and Glaister, 2002; Sterner, 2007).

Table 2
Overview of simulations.

Scenario	Description	Scenario	Description
Benchmark	No carbon regulation	EU ETS	EU ETS sectors trade permits across Europe; other sectors are regulated using carbon taxes differentiated by sectors
Sectoral	Carbon taxes differentiated by sectors	EU ETS transport closed	EU ETS system; transport sectors are allowed to trade permits across Europe; no trade between transport and EU ETS sectors
National	Permit trade across sectors but not across European regions	EU ETS transport	Transport sectors are included into the EU ETS
Full trade	Permit trade across sectors and European regions	EU ETS transport exempted	Transport sectors are excluded from carbon regulation; reduction burden of EU ETS sectors is increased to hold overall reduction requirement constant

No regulation applies for non-Annex I countries. The scenarios differ in the way how the European countries achieve their reduction targets (Table 2). The Annex I region implements its reduction target by a national emission trading; i.e. all sectors within this region are allowed to trade emission allowances. In all scenarios regions redistribute the income of carbon regulation as a lump sum transfer to the representative household by holding government purchases constant.

In the calibrated benchmark no carbon policy takes place. In the Sectoral scenario, European countries allocate the reduction burden uniformly to all sectors. In the national scenario, allowance trading across sectors is allowed. Additional trading across European countries is permitted in the Full Trade Europe scenario. The EU ETS scenario implements the European emission trading system in its current state: electricity sectors, refineries, and emission intensive industries trade allowances across Europe while the remaining sectors, including transportation, are regulated by sector carbon restrictions i.e. sectoral fuel taxes. Regions with negative reduction requirement, i.e. they are allowed to increase emissions, cap emissions of non-EU ETS sectors at the benchmark level and allocate their excess budget to the EU ETS. In the EU ETS Transport Closed scenario, industrial and household transports are allowed to trade emissions across Europe on top of the EU ETS. However, no trade between transport and EU ETS sectors takes place. This is equivalent to a European-wide uniform carbon tax in the transport

Table 3
Welfare changes compared to benchmark (% Hicksian equivalent variation).

	Sectoral	National	Full Trade Europe	EU ETS	EU ETS transport closed	EU ETS transport	EU ETS transport exempted
Benelux	−1.75	−0.90	−0.34	−1.65	−1.23	−0.51	−0.45
Denmark	−1.73	−0.80	−0.37	−1.53	−0.79	−0.40	−0.38
Finland	−1.70	−0.78	−0.35	−1.59	−1.24	−0.63	−0.58
France	−1.52	−0.68	−0.21	−1.48	−0.98	−0.35	−0.29
Germany	−1.35	−0.47	−0.28	−1.28	−1.01	−0.41	−0.35
Italy	−1.48	−0.63	−0.25	−1.41	−1.05	−0.55	−0.50
Poland	−0.07	−0.07	0.23	−0.01	−0.20	0.14	0.21
Spain	−0.79	−0.26	−0.20	−0.76	−0.79	−0.21	−0.15
Sweden	−1.61	−0.83	−0.25	−1.53	−1.07	−0.39	−0.33
UK	−1.05	−0.35	−0.18	−1.00	−0.62	−0.20	−0.17
Western EU	−0.82	−0.28	−0.23	−0.78	−0.77	−0.26	−0.20
Eastern EU	−0.08	−0.07	0.22	−0.03	−0.28	0.15	0.24
EU 27	−1.22	−0.49	−0.21	−1.16	−0.87	−0.33	−0.28
Annex I	−0.08	−0.07	−0.06	−0.07	−0.07	−0.06	−0.06
Rest of the world	−0.05	−0.03	−0.02	−0.04	−0.05	−0.02	−0.02

sector. Trade between transport and EU ETS sectors is permitted in the EU ETS Transport scenario, which fully integrates transportation into the EU ETS. Finally, EU ETS Transport Exempted implements the European emission trading system and exempts transportation from carbon regulation. The reduction requirement of the transport sector is shifted to the EU ETS. Therefore, electricity, refinery and energy intensive sectors face a higher reduction burden.

For scenarios, which do not differentiate carbon regulation across sectors (Sectoral, National, Full Trade Europe), the welfare ranking (Table 3) is as theory predicts: implementing carbon regulation by a sector approach shows high welfare losses across Europe.[3] Eastern European countries and Poland only exhibit small welfare changes since they face negative reduction requirements. Consequently, carbon prices in these regions drop to zero. Allowing for national carbon trade significantly reduces the cost of regulation since marginal abatement cost (MAC) equalize across sectors. Thus, CO_2 is abated in sectors with the lowest cost. A further decrease results if carbon permits are additionally traded across Europe (Full trade Europe).

Regulating emissions under the EU ETS improves welfare compared to the Sectoral scenario since the EU ETS sectors electricity, refineries and energy-intensive industries equalize MAC. However, welfare losses in the EU ETS approach are higher than in a National trading system. This shows that the gain of allowing permit trade between sectors is higher than of allowing trade across Europe. The European permit price becomes 1.83 \$/t CO_2, while other sectors show high carbon taxes. Especially in the transport sectors taxes are very high (up to 267 \$/t CO_2 for Sweden). The low carbon price in the EU ETS system is explained by the assumption that eastern European countries allocate their excess budget to the EU ETS.

Implementing a closed emission trading system for transportation (EU ETS transport closed) further lowers the regulation costs. However, European welfare losses are still approximately twice as high as in the National trade system. The permit price in the EU ETS sector becomes 1.77 \$/t CO_2. In the trading system for transport sectors the carbon price is still at a high level of 73.42 \$/t CO_2. Even if transport sectors are permitted to trade allowances across Europe, the marginal abatement costs are high compared to the EU ETS sectors.

The large difference in the MACs explains the significant welfare improvement of including transportation into the EU ETS (EU ETS transport). Transport sectors buy permits from the electricity and energy intensive sectors and increase emissions. Consequently, the electricity and energy intensive sectors have to decrease emissions. Therefore, MACs are rising in these sectors and falling in transport sectors. As a result, including transport sectors into the EU ETS raises the European emission allowances price to 6.63 \$/t CO_2. The integration of the transport sector leads to welfare costs even below the cost of coexisting National emission trading systems.

Finally, the implications of exempting transportation from carbon regulation and increasing the reduction burden of EU ETS sectors is examined (*EU ETS Transport Exempted*). As the abatement burden is shifted to the EU ETS system, the European allowances price increases to 7.73 \$/t CO_2. The exemption of transport from carbon policy leads to a further welfare improvement compared to the extended EU ETS system (*EU ETS Transport*). This result is explained by high pre-existing fuel taxes in the transport sector. The pre-existing tax leads to two effects (e.g. Parry, 1995). First, tax base erosion occurs, i.e. the additional carbon price on the transport fuel increases the price and, consequently, lowers demand. Therefore, the income of the pre-existing tax decreases leading to a lower transfer to households. However, the tax loss is more than outweighed by the income of carbon regulation. Second and more important, tax interaction occurs. Cost effective environmental theory requires that the effective carbon price equalizes across sectors. The pre-existing tax on transport fuels can be interpreted as an already existing carbon price in the transport sector. Therefore, the exemption of transport yields carbon prices closer to uniform across sectors and, thus, increases cost effectiveness of carbon regulation.

[3] Since the benefit of carbon regulation, the decrease in the global warming process, is not included, welfare results only reflect the cost side of the policy and thus are generally negative.

The welfare improving result of excluding transportation from environmental regulation, however, should be considered with caution since the presented approach neglects other externalities of transportation such as congestion, accident, and noise externalities. Part of the pre-existing tax has to be devoted to the internalization of these externalities. If a policy instrument addressing carbon emissions reduces the demand for road transport, these externalities will decrease as well. Consequently, there is a further positive welfare effect. Put differently, since excluding transportation leads to an increase in traffic, negative welfare effects occur by the increase of other external cost which could outweigh the positive effect of decreasing the described tax-interaction effect.

4. Conclusions

This paper simulated different market-based approaches for the regulation of transport sector CO_2 emissions with a static multi-region CGE model for the EU27. Besides imposing fuel taxes, the possibility of a closed emission trading system for transportation and inclusion into the EU ETS were examined. The simulations show a clear-cut ranking of regulation approaches: establishing a European-wide emission trading system for transport sectors, which coexists beside the EU ETS, lowers the cost of carbon regulation compared to fuel tax in the transport sector. Furthermore, integrating transportation into the existing EU ETS further reduces regulation cost. Due to the high pre-existing fuel taxes in transport sectors across Europe the approach with the lowest welfare cost is to exempt transport from carbon regulation and to increase the reduction burden of EU ETS sectors. Furthermore, the results show that if policy makers decide to impose regulation on the level of transport fuel then a unified European approach by integrating transportation into the EU ETS is the best alternative.

References

Albrecht, J., 2000. The diffusion of cleaner vehicles in CO_2 emission trading designs. Transportation Research D 5, 385–401.
Armington, P.S., 1969. A theory of demand for products distinguished by place of production. International Monetary Fund Staff Paper 16, 159–176.
Burniuax, J.-M., Truong, T., 2002. GTAP-E: An Energy-Environmental Version of the GTAP Model, GTAP Technical Paper 16.
Dimaranan, B. (Ed.), 2006. The GTAP 6 Data Base. West Lafayette, Center for Global Trade Analysis, Department of Agriculture Economic, Purdue University.
European Commission, 2003. Establishing a Scheme for Greenhouse Gas Emission Allowance Trading within the Community and Amending Council Directive 96/61/EC. Directive 2003/87/EC of the European Parliament and the Council. Published in: Official Journal of the European Community L 275/32 2003.
European Commission, 2009a. Regulation (EC) No. 443/2009 of the European Parliament and of the Council of 23 April 2009 Setting Emission Performance Standards for New Passenger Cars as Part of the Community's Integrated Approach to Reduce CO_2 Emissions from Light-duty Vehicles, Official Journal of the European Union, L140/1. 443/2009/EC.
European Commission, 2009b. Decision No. 406/2009/EC of the European Parliament and of the Council of 23 April 2009 on the Effort of Member States to Reduce their Greenhouse Gas Emissions to Meet the Community's Greenhouse Gas Emission Reduction Commitments up to 2020. Official Journal of the European Union, L 140/136. 406/2009/EC.
EUROSTAT, 1999. Household Budget Survey of 1999. Luxembourg.
EUROSTAT, 2007. Pocketbook Energy, Transport, and Environment Indicators, Luxembourg.
Graham, D.J., Glaister, S., 2002. The demand for automobile fuel: a survey of elasticities. Journal of Transport Economics and Policy 36, 1–26.
Intergovernmental Panel on Climate Change, 2006. Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. Japan, Institute for Global Environmental Strategies.
Parry, I.W., 1995. Pollution taxes and revenue recycling. Environmental Economics and Resource Management 29, 67–77.
Paltsev, S., Viguier, L., Babiker, M., Reilly, J., Tay, K.H., 2004. Disaggregating Household Transport in the MIT-EPPA Model. MIT Joint Program on the Science and Policy of Global Change, Technical Note 5.
Paltsev, S., Jacoby, D., Reilly, J., Viguier, L., Babiker, M., 2005a. Modeling the transport sector: the role of existing fuel Taxes. In: Loulou, R., Waaub, J., Zaccour, G. (Eds.), Climate Policy. Energy and Environment: 25th Anniversary of the Group for Research in Decision Analysis, vol. 3. Springer-Verlag, New York.
Paltsev, S., Reilly, J., Jacoby, H., Eckaus, R., McFarland, J., Sarofim, M., Asadoorian, M., Babiker, M., 2005b. The MIT Emission Prediction and Policy Analysis (EPPA) Model: Version 4. MIT Joint Program on the Science and Policy of Global Change, Report 125.
Raux, C., 2004. The use of transferable permits in transport policy. Transportation Research D 9, 185–197.
Sterner, T., 2007. Fuel taxes: an important instrument for climate policy. Energy Policy 35, 3194–3202.
World Resource Institute, 2008. Climate Analysis Indicator Tool. <http://cait.wri.org/> (assessed 10.12.08).