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Integrating emissions transfers into policy-making

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Net emissions transfers via international trade from developing to developed countries have increased fourfold in the past two decades—from 0.4 $GtCO_2$ in 1990 to 1.6 $GtCO_2$ in 2008[1]. Consumption of goods and services in developed countries is one of the main driving forces of those emissions transfers[2,3]. Therefore several proposals have been made to assign the responsibility for those emissions to the beneficiary, that is, to the consumer[4–6]. Although consumption-based analyses have become popular[7–9], few proposals have been made for integrating emissions transfers into actual policy making. This study advances and critically evaluates three potential policy options that could be integrated in the climate-policy framework of developed countries. An energy–economic model with global coverage is used for the analysis. I find that connecting emissions transfers to international offset responsibilities is the most promising option from an environmental and economic perspective and may provide another rationale for international climate finance. The two alternative policy options of adjusting domestic emissions targets in developed countries and of implementing carbon-related tariffs and export subsidies are found to be environmentally ineffective in the latter case and economically detrimental, especially for developing countries, in both cases.

Emission transfers provide a lens on the emissions responsibilities that are driven by the import and consumption demands of a country. They denote the balance of emissions embodied in trade, that is, the emissions embodied in exports minus those embodied in imports[10]. In the current landscape of subglobal climate policies, emissions transfers can undermine the stringency of domestic emissions-reduction targets as countries with emissions-reduction targets can import emissions-intensive products from non-regulating countries[11]. This so-called 'weak carbon leakage'[1,2] leads to distributional changes in the burden sharing of emissions responsibilities as the importing country gives the appearance of being less polluting and the exporting country more polluting. In addition, it decreases the emissions coverage and the environmental effectiveness of existing climate policies.

Unresolved questions persist regarding the appropriate policy response in the medium term. An ideal policy response against weak carbon leakage would be to extend the regional coverage of climate policies. Efforts within the United Nations Framework Convention on Climate Change (UNFCCC) are moving into that direction, but the implementation of a new global agreement with broad coverage may not eventuate for decades. A second-best approach for the medium term could therefore be to integrate emissions transfers into existing climate policies. Using emissions transfers as a policy lever could increase the emissions coverage of subglobal climate policies and highlight the consumption-based emissions responsibilities that are currently missed in the territorial emissions accounting system.

Here I analyse three potential policy options that account for emissions transfers and incorporate consumption-based emissions responsibilities into the current climate policy framework of industrialized countries (Table 1). Those policies include adjusting domestic emissions-reduction targets for emissions transfers (DOM scenario), offsetting emissions transfers by financing emissions reductions in the emissions-exporting regions (CDF scenario), and adjusting import and export prices of goods in proportion to their carbon content, that is, extending the domestic carbon price by levying carbon tariffs on imports from non-climate regulating regions and providing export rebates for goods exported to those regions by the regulating regions (BCA scenario). Although some of those policies have been discussed before[12–20], here I present the first consistent analysis of the environmental and economic impacts of those policy options from the perspective of international emissions transfers.

I use a global energy–economic model to analyse the different policy options. The model provides a comprehensive and microeconomically consistent representation of price-dependent market interactions, which allows one to analyse the policy-induced adjustment effects on regional production, consumption and CO_2 emissions[21–23]. The model is calibrated to empirical benchmark data for the year 2007. The base model resolves 11 regions and 8 aggregated commodity sectors (see Supplementary Table 1). Regions are grouped into Annex I countries that have agreed to binding emissions reduction targets under the UNFCCC, and developing non-Annex I countries that have not agreed to binding emissions reductions but who have stated the requirement of clean-development financing to implement mitigation and adaptation measures. In the reference scenario, Annex I countries undertake emissions-reduction efforts of current ambition. Further details on the scenario specifications and model calibration can be found in Methods.

Instead of focusing on all emissions transfers embodied in trade, the study's main scenarios concentrate on those emissions transfers that are embodied in the energy-intensive and trade-exposed sectors (see Methods for details on the sectoral composition). In this way, the political and practical feasibility of the policies studied increases owing to confined needs on the measuring and monitoring of emission flows. In line with the study's focus on the consumption-based emissions responsibilities of Annex I countries, I am netting the embodied emissions between trading partners, but not across them, that is, net bilateral imports of embodied emissions from one non-Annex I country are not offset by net bilateral exports of embodied emissions to another non-Annex I country.

In the reference scenario, the bilateral energy-intensive emissions transfers from Annex I to non-Annex I countries amount to 346 $MtCO_2$, which constitutes 18% of the total net emissions transfer (see Supplementary Figs 2 and 3 for sectoral and regional

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Table 1 | Overview of policy scenarios.

Policy scenario	Description	Comments
REF	Annex I countries reduce their CO_2 emissions by 10% below their 2007-levels.	In line with current emissions-reduction pledges submitted to the UNFCCC (ref. 29), but implemented as an overall cap, which allows for emissions trading among Annex I countries.
DOM	Annex I countries adjust their emissions-reduction targets for emissions transfers from non-Annex I countries, that is, they increase their target if the emissions embodied in imports exceed those embodied in exports.	Increases the burden on net importers of emissions, but may also have negative repercussions for the net exporting regions as a result of decreased import demand and higher export prices in the importing region[14].
CDF	Annex I countries offset their emissions transfers by financing emissions-reduction projects in the emissions-transferring non-Annex I countries.	Similar to the CDM of the Kyoto Protocol[15,16]; based on the premise that emissions reductions can be achieved more cost-effectively in developing countries than in developed ones owing to the availability of low-cost abatement options.
BCA	Annex I countries apply their domestic carbon price to emissions transfers by levying carbon tariffs on commodities imported from non-Annex I countries and exempting the commodities exported to non-Annex I countries.	Addresses competitive issues of domestic industries as it increases import prices and decreases export prices; highly contentious on the political level as carbon tariffs may shift a considerable burden with significant welfare losses to the targeted exporting (developing) countries[17–19].

The main policy scenarios focus on bilateral net energy-intensive emissions transfers between Annex I and non-Annex I countries.

decompositions). In the Supplementary Information I show that the qualitative insights of this study are not affected if the focus were to be on netted energy-intensive emissions transfers, which amount to 295 $MtCO_2$ (Supplementary Section 2.2), or on emissions transfers embodied in all goods, which amount to 1,639 $MtCO_2$ (Supplementary Section 5.4).

Figure 1 summarises the results of the environmental, economic and integrated analyses of the policy options considered. Figure 1a details the changes in CO_2 emissions and emissions transfers (Supplementary Fig. 4 and Table 3 show the changes in energy-intensive emissions transfers and list absolute values); the effects on policy-induced (strong) carbon leakage are shown in Supplementary Fig. 5) Figure 1a indicates that changes in emissions transfers do not necessarily affect global emissions levels. The border-carbon-adjustment (BCA) scenario reduces energy-intensive and total emissions transfers, but does not lead to sizable emissions reductions in non-Annex I countries or globally (as the direct reductions are modest and partly offset by increased production of goods other than the energy-intensive ones, see Supplementary Table 5). In contrast, the domestic-target-adjustment (DOM) scenario and the clean-development-finance (CDF) scenario have little effect on emissions transfers, but have a significant impact on global emissions—through domestic emissions reductions in Annex I countries in the DOM scenario and through sponsored emissions reductions in non-Annex I countries in the CDF scenario. The DOM scenario increases emissions transfers to Annex I countries, which may lead to successively more stringent reduction targets for Annex I countries in a dynamic setting[14].

Figure 1b details the economic analysis of the four model scenarios. I first analyse the economic costs of each policy scenario in terms of changes in Hicksian compensating variation (HCV). HCV is a common social welfare measure denoting how much money would be needed to compensate the representative consumer in each region for policy-induced price changes after they occur[24]. Changes in GDP that focus on the production side of the economy show similar distributional trends and are listed in Supplementary Table 6. Detailed regional impacts are listed in Supplementary Table 7 and, with a higher regional resolution, in Supplementary Table 13. The economic analysis focuses on the distribution of costs in each scenario and does not contain information on a scenario's relative cost-effectiveness or its relative benefit, because global emissions reductions differ across scenarios. I assess the scenarios' relative trade-offs in a second step, which is described further below.

In the reference (REF) scenario, the emissions-reduction efforts of Annex I countries have an impact on the welfare levels of both Annex I and non-Annex I countries. The introduction of carbon pricing in Annex I countries increases domestic prices, which reduces consumption in Annex I countries and affects non-Annex I countries through increased export prices and reduced import demand, in particular of fossil fuels (see Supplementary Fig. 6).

The BCA scenario is characterized by an unequal distribution of the economic burden between Annex I and non-Annex I countries. Welfare in the tariff-implementing Annex I countries increases compared to the REF scenario, in particular as a result of the influx of tariff revenues, which amount to US$7.9 billion in total. On the other hand, non-Annex I countries experience significant welfare losses as a result of the new tariff barrier on energy-intensive goods (and the associated changes in trade, see Supplementary Fig. 7). Recycling the tariff revenues can alleviate part of those losses, but a negative net impact remains, also if those revenues are used for clean-development investments (see Supplementary Table 8 and ref. 20). The directional impacts also remain if BCAs are perceived as an implicit emissions tax on energy-intensive production instead of an output tax on exports (see Supplementary Table 8 and ref. 25).

In the DOM scenario all additional emissions reductions are shouldered by Annex I countries. As a result, the domestic CO_2 price increases by 33% to 27 US$/$tCO_2$ from 21 US$/$tCO_2$ in the REF scenario. Higher CO_2 prices in Annex I countries increase domestic prices and reduce consumption. This also affects non-Annex I countries through increased export prices and reduced import demand, especially of carbon-intensive fossil fuels (see Supplementary Fig. 6). Consequently, both Annex I and non-Annex I countries experience welfare losses and global welfare decreases below the reference level.

The CDF scenario allows Annex I countries to offset their consumption-based emissions responsibilities through clean-development investments in the emissions-exporting developing countries. This access to international offsets significantly reduces the negative economic impacts of the DOM scenario. In line with the direction of clean-development investments, the CDF scenario's impact on non-Annex I countries is slightly positive,

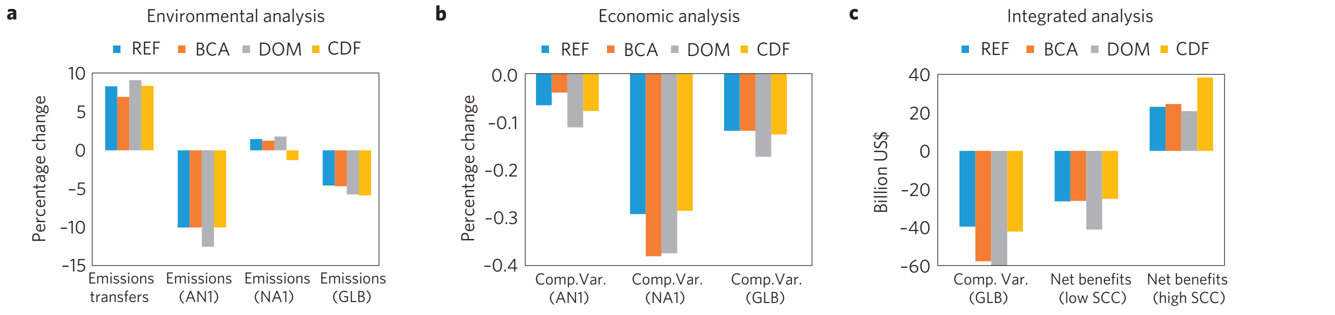

Figure 1 | Environmental, economic, and integrated analyses of the four policy scenarios. a, The environmental analysis considers percentage changes in net emissions transfers from non-Annex I countries to Annex I countries, and emissions in Annex I countries (AN1), non-Annex I countries (NA1), and globally (GLB). **b**, The economic analysis assesses economic impacts in terms of regional percentage changes in HCV (Comp. Var.). **c**, The integrated analysis includes a cost-effectiveness analysis of the policy scenarios at equal emissions levels, expressed in terms of HCV (in billion US$; the REF scenario is associated with higher emissions, so that its compensating variation is only shown for scale), and a cost–benefit analysis of the policy scenarios for low and high social costs of carbon (SCC), expressed as net benefits (in billion US$).

whereas its impact on Annex I countries is slightly negative. Total investments amount to US$2.8 billion (see Supplementary Table 9). Incorporating more regional detail and greater inefficiencies of clean-development projects increases the investment needs but has modest economic impacts, whereas decreasing transaction costs or relaxing the destination principle and directing clean-development investments to the least cost option decreases them (see Supplementary Figs 8 and 9 and Table 12).

For ranking the different policy scenarios, I integrate the environmental and economic impacts in both a cost-effectiveness analysis and a cost–benefit analysis. The cost-effectiveness analysis assesses the scenarios' costs of achieving the same level of global emissions reductions, whereas the cost–benefit analysis monetizes the economic benefits of the emissions reduced without equalizing their levels and assesses the scenarios' net benefits. Each approach allows for an economically consistent ranking of policy options. For the cost-effectiveness analysis, I adopt a global emissions-reduction target (similar to that of the CDF scenario) which offsets the consumption-based energy-intensive emissions responsibilities of Annex I countries (see Supplementary Section 4.1). For monetizing emissions reductions in the cost–benefit analysis, I adopt the low and high values of the US Government's social cost of carbon estimates, which are based on an integrated-assessment modelling exercise[26,27] (see Supplementary Section 4.2).

Figure 1c shows the results of the cost-effectiveness and cost-benefit analyses. The CDF scenario yields the largest net benefits among the policy scenarios—up to two thirds more benefits than the REF scenario—and is also the most cost-effective in reducing global emissions by an amount equal to energy-intensive emissions transfers. (note that the REF scenario is associated with higher emissions, so that its compensating variation is only shown for scale in the cost-effectivness analysis of Fig. 1c). The BCA scenario also yields greater net benefits than the REF scenario, but it has up to a third less net benefits than the CDF scenario and is a quarter less cost-effective. The least preferable scenario is the DOM scenario, which is a third less cost-effective than the CDF scenario and associated with net costs compared to the REF scenario for both a low and a high social cost of carbon. Supplementary Fig. 11 shows that the scenario ranking is maintained for different social-welfare specifications.

Although the numerical results presented above hold strictly only for a specific set of parameters, a comprehensive sensitivity analysis indicates that the relative and directional effects are robust with respect to changes in key model parameters, such as the fossil-fuel supply elasticities, fossil-fuel price responses, trade elasticities, emissions-reduction targets and regional and sectoral aggregation (see Supplementary Section 5). Broadening the policies' coverage of emissions transfers from the energy-intensive ones to all emissions transfers increases the environmental and economic impacts of each policy scenario—for example clean-development investments increase to about US$50 billion and global emissions reduction to over 10%—but the scenarios' relative trade-offs are preserved (see Supplementary Table 14).

Although the static, energy–economic framework used in this study enables a comprehensive integrated analysis on a medium timescale, it necessarily abstains from various aspects, such as political and administrative details and the long-term evolution of economic and environmental impacts. With those caveats in mind, the results presented above suggest that connecting emissions transfers to international offset responsibilities could be the most promising option, from an environmental and economic perspective, for integrating consumption-based emissions responsiblities into the current climate policy framework. In contrast, the other two policy options—adjusting domestic emissions targets in developed countries and implementing carbon-related tariffs and export subsidies—are likely to be economically detrimental, and the second option also environmentally ineffective.

However, there are several critical issues associated with connecting clean-development financing to emissions transfers. First, trade-active countries, such as China, would receive a high proportion of financing, whereas the least-developed countries with low export volumes would receive very little. Second, some non-Annex I countries could be incentivised to increase the carbon content of their traded goods to receive more investments. Third, the allocation of clean-development investments in proportion to emissions transfers is not the most economically efficient way of offsetting emissions transfers. The first and third issues could potentially be addressed by channelling part of the investments through a global climate fund. The disbursement could then be made according to greatest need or greatest abatement potential, subject to political negotiation. The second issue can be addressed by agreeing on specific reference years or periods. Either modification would not alter the qualitative conclusions of this study.

The implementation of a new global agreement with broad coverage may not eventuate for decades. Incorporating emissions transfers into the current climate policies of industrialized countries presents a second-best policy option to increase the emissions coverage and environmental effectiveness of subglobal climate policies in the medium term. Accounting for consumption-based emissions responsibilities through emissions transfers may further facilitate international climate negotiations if their burden is ascribed equitably. Connecting emissions transfers to international offset responsibilities in developing countries goes in that direction and could provide an additional rationale for international climate finance.

Methods

This paper uses a multi-region, multi-sector, static computable general equilibrium model of global trade and energy use[18]. The model provides a comprehensive representation of price-dependent market interactions based on microeconomic theory[21–23]. It is based on the optimizing behaviour of economic agents, that is, consumers maximize welfare subject to budget constraints and producers combine intermediate inputs and primary factors at least cost to produce output. Energy resources are included as primary factors whose use is associated with the emission of carbon dioxide (CO_2). The production, consumption and trade of goods is described by nested constant-elasticity-of-substitution cost functions which characterize substitution possibilities between inputs.

The model is calibrated to the database version 8 of the Global Trade Analysis Project[28]. The database includes information on bilateral trade, intermediate demand, direct and indirect taxes on imports and exports, as well as CO_2 emissions from the combustion of fossil fuels for the benchmark year of 2007. For the focus of this study, I explicitly resolve four Annex I and seven non-Annex I regions, and differentiate between five energy commodities (coal, natural gas, crude oil, refined oil and electricity), energy-intensive goods, transport services, and a composite of all other goods. Energy-intensive goods include iron and steel; chemicals, including plastics and petrochemical products; non-ferrous metals, including copper and aluminium; and non-metallic minerals, including cement. The Supplementary Information provides further details on the model formulation and calibration.

I implement four policy scenarios into the energy–economic model. The main policy scenarios are a border-carbon-adjustment scenario, a domestic-target-adjustment scenario, and a clean-development finance scenario. The scenarios are implemented on top of a reference scenario, in which Annex I countries reduce their CO_2 emissions by 10% below their 2007-levels. This magnitude of emissions reductions is in line with current emissions-reduction pledges submitted to the UNFCCC (ref. 29). The emissions reductions are implemented as an overall cap, which allows emissions trading among Annex I countries.

The border-carbon-adjustment scenario adjusts the pricing of carbon at Annex I countries' borders. This includes the implementation of carbon tariffs by Annex I countries on energy-intensive imports from non-Annex I countries and export rebates in proportion to the domestic carbon price for energy-intensive goods exported from Annex I countries to non-Annex I countries. The tariff level is determined endogenously in proportion to the carbon content of imports and the price of carbon in Annex I countries. The carbon content of imports consists of all direct and indirect CO_2 emissions (excluding process emissions) used for producing the goods in the country of origin plus the transportation services needed for exporting them to Annex I countries. The carbon contents are computed by a recursive diagonalization algorithm described in ref 18. The Supplementary Information considers alternative BCA specifications on the use of carbon-tariff revenues and tax incidence.

The DOM adjusts Annex I countries' emissions-reduction targets for energy-intensive emissions transfers from non-Annex I countries. The emissions embodied in net imports from a specific non-Annex country are subtracted from the importing Annex I country's emissions target. This results in more stringent targets for countries with net imports of embodied emissions. The embodied emissions are netted between the trading partners, but not across them, that is, net bilateral imports of embodied emissions from one non-Annex I country are not offset by net bilateral exports of embodied emissions to another non-Annex I country. This corresponds to this study's focus on the bilateral consumption-based emissions responsibilities of Annex I countries in the climate-policy framework of those countries.

The CDF allows Annex I countries to offset their consumption-based emissions responsibilities vis-à-vis non-Annex I countries by financing clean-development projects in those countries. I use a new, microeconomically consistent modelling framework to represent clean-development investments in non-Annex I countries as a combination of sectoral output subsidies and emissions taxes[30]. The emissions taxes induce the adoption of more energy-efficient and more expensive production technologies, whereas the output subsidies compensate the representative firm for the increase in production costs. The funds for the clean-development investments cover the subsidy payments net of emissions-tax revenues and are deducted from the financing country's budget balance. I focus on clean-development investments in the electricity sector, which is in line with the sectoral distribution of projects under the Clean Development Mechanism (CDM) of the Kyoto Protocol[15]. Also with reference to the CDM, I assume that clean-development investments are subject to transaction costs of 30% (see Supplementary Section 3.3). The magnitude of clean-development investments is iterated within the energy–economic model until the bilateral net emissions embodied in energy-intensive imports to each Annex I countries are offset. The Supplementary Information contain further details on the CDF modelling approach.

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References

1. Peters, G., Minx, J., Weber, C. L. & Edenhofer, O. Growth in emission transfers via international trade from 1990 to 2008. *Proc. Natl Acad. Sci. USA* **108,** 8903–8908 (2011).
2. Hertwich, E. G. & Peters, G. P. Carbon footprint of nations: A global, trade-linked analysis. *Environ. Sci. Technol.* **43,** 6414–6420 (2009).
3. Davis, S. J. & Caldeira, K. Consumption-based accounting of CO_2 emissions. *Proc. Natl Acad. Sci. USA* **107,** 5687–5692 (2010).
4. Rose, A. Reducing conflict in global warming policy: The potential of equity as a unifying principle. *Energy Policy* **18,** 927–935 (1990).
5. Munksgaard, J. & Pedersen, K. A. CO_2 accounts for open economies: Producer or consumer responsibility? *Energy Policy* **29,** 327–334 (2001).
6. Ferng, J-J. Allocating the responsibility of CO_2 over-emissions from the perspectives of benefit principle and ecological deficit. *Ecol. Econ.* **46,** 121–141 (2003).
7. Wiedmann, T., Lenzen, M., Turner, K. & Barrett, J. Examining the global environmental impact of regional consumption activities—Part 2: Review of input–output models for the assessment of environmental impacts embodied in trade. *Ecol. Econ.* **61,** 15–26 (2007).
8. Wiedmann, T. A review of recent multi-region input–output models used for consumption-based emission and resource accounting. *Ecol. Econ.* **69,** 211–222 (2009).
9. Jakob, M. & Marschinski, R. Interpreting trade-related CO_2 emission transfers. *Nature Clim. Change* **3,** 19–23 (2012).
10. Muradian, R., O'Connor, M. & Martinez-Alier, J. Embodied pollution in trade: Estimating the 'environmental load displacement' of industrialised countries. *Ecol. Econ.* **41,** 51–67 (2002).
11. Wyckoff, A. W. & Roop, J. M. The embodiment of carbon in imports of manufactured products: Implications for international agreements on greenhouse gas emissions. *Energy Policy* **22,** 187–194 (1994).
12. Peters, G. P. & Hertwich, E. G. CO_2 embodied in international trade with implications for global climate policy *Environ. Sci. Technol.* **42,** 1401–1407 (2008).
13. Fischer, C. Trade's growing footprint. *Nature Clim. Change* **1,** 146–147 (2011).
14. Springmann, M., Zhang, D. & Karplus, V. J. *Consumption-based Adjustment of China's Emissions-Intensity Targets: An Analysis of Its Potential Economic Effects* Report 241 (MIT Joint Program on the Science and Policy of Global Change, 2013) .
15. Gillenwater, M. & Seres, S. The Clean Development Mechanism: A review of the first international offset programme. *Greenhouse Gas Meas. Manag.* **1,** 179–203 (2011).
16. Anger, N., Böhringer, C. & Moslener, U. Macroeconomic impacts of the CDM: The role of investment barriers and regulations. *Clim. Policy* **7,** 500–517 (2007).
17. Babiker, M. H. & Rutherford, T. F. The economic effects of border measures in subglobal climate agreements. *Energy J.* **26,** 99–125 (2005).
18. Böhringer, C., Carbone, J. C. & Rutherford, T. F. *Embodied Carbon Tariffs* NBER Working Paper 17376 (National Bureau of Economic Research, 2011) .
19. Winchester, N., Paltsev, S. & Reilly, J. M. Will border carbon adjustments work? *BE J. Econ. Anal. Policy* **11,** 7.1–7.27 (2011).
20. Springmann, M. Carbon tariffs for financing clean development. *Clim. Policy* **13,** 20–42 (2013).
21. Böhringer, C., Rutherford, T. F. & Wiegard, W. *Computable General Equilibrium Analysis: Opening A Black Box* Discussion Paper No. 03-56 (Zentrum für Europäische Wirtschaftsforschung (ZEW), 2003) .
22. Bergman, L. in *Handbook of Environmental Economics* (eds Mäler, K-G. & Vincent, J. R.) Ch. 24, 1273–1306 (Elsevier, 2005).
23. Wing, I. S. in *International Handbook On The Economics Of Energy* (eds Evans, J. & Hunt, L. C.) 332–366 (Edward Elgar, 2009).
24. Hazilla, M. & Kopp, R. J. Social cost of environmental quality regulations: A general equilibrium analysis. *J. Polit. Econ.* **98,** 853–873 (1990).
25. Winchester, N. The impact of border carbon adjustments under alternative producer responses. *Am. J. Agr. Econ.* **94,** 354–359 (2012).
26. Interagency Working Group on Social Cost of Carbon *Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12866* (United States Government, 2010) .
27. Interagency Working Group on Social Cost of Carbon *Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866* (United States Government, 2013) .
28. in *Global Trade, Assistance, and Production: The GTAP 8 Data Base* (eds Narayanan, B., Aguiar, A. & McDougall, R.) (Center for Global Trade Analysis, Purdue University, 2012).
29. Levin, K. & Bradley, R. *Comparability of Annex I Emission Reduction Pledges* WRI Working Paper (World Resources Institute, 2010) .
30. Böhringer, C., Rutherford, T. F. & Springmann, M. *Clean-development Investments: An Incentive-compatible CGE Modelling Framework* Oldenburg Discussion Papers in Economics (University of Oldenburg, 2013) .

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Additional information

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Competing financial interests

The author declares no competing financial interests.