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Coal taxes as supply-side climate policy: a rationale for major exporters?

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Abstract The shift away from coal is at the heart of the global low-carbon transition. Can governments of coal-producing countries help facilitate this transition and benefit from it? This paper analyses the case for coal taxes as supply-side climate policy implemented by large coal exporting countries. Coal taxes can reduce global carbon dioxide emissions and benefit coal-rich countries through improved terms-of-trade and tax revenue. We employ a multi-period equilibrium model of the international steam coal market to study a tax on steam coal levied by Australia alone, by a coalition of major exporting countries, by all exporters, and by all producers. A unilateral export tax has little impact on global emissions and global coal prices as other countries compensate for reduced export volumes from the taxing country. By contrast, a tax jointly levied by a coalition of major coal exporters would significantly reduce global emissions from steam coal and leave them with a net sector level welfare gain, approximated by the sum of producer surplus, consumer surplus, and tax revenue. Production taxes consistently yield higher tax revenues and have greater effects on global coal consumption with smaller rates of carbon leakages. Questions remain whether coal taxes by major suppliers would be politically feasible, even if they could yield economic benefits.

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1 Introduction

Coal is both the fossil fuel with the highest carbon intensity per unit of energy and an energy carrier that is globally abundant (Rogner et al. 2012). Even though coal use is in decline in most developed countries and global coal use has not grown for several years, many developing countries exhibit increasing coal consumption (Steckel et al. 2015). The International Energy Agency (IEA/OECD 2016a) projects global coal use to increase under its 'current policy' scenario and to stay stable for decades under its 'new policies' scenarios. This is in stark contrast to the climate policy imperative: if climate change is to be kept within tolerable limits, most of the proven global coal reserves need to remain in the ground (Meinshausen et al. 2009; McGlade and Ekins 2015).

The vast majority of climate policies are designed to reduce the demand for fossil fuels. However, the price-dampening effect of such policies put fossil fuel exporters at a disadvantage, which reduces their willingness to join global efforts to mitigate climate change. By contrast, supply-side climate policies—that reduce fossil fuel use through supply constraints—could potentially leave energy exporters better off through improved terms-of-trade. Moreover, they can be attractive to implementing governments as they raise fiscal revenue, which could be deployed, among other uses, on the transition to low-carbon energy systems.

In this paper, we focus on coal taxes, investigating both the incentives for implementation and the impacts of withholding supply. Specifically, we consider hypothetical taxes on the export or production of steam coal[1] that are levied by Australia, the world's second largest steam coal exporter, or alternatively by a coalition of major exporters.[2] We thereby investigate effects of coal taxes on CO_2 emissions from steam coal, tax revenues, and shifts in the global patterns of consumption, production, and trade of steam coal. To this end, we set up an equilibrium model of the steam coal sector, building on, and further developing, COALMOD-World (Haftendorn et al. 2012a, b; Holz et al. 2015, 2016).[3] Our model features endogenous investments in production and transportation capacities in a multi-period framework and represents the substitution relation between imports and domestic production of steam coal. Hence, in response to coal taxes, short-run adjustments (e.g. import substitution effects) and long-run reactions (e.g. capacity expansions) of competing exporters and importing countries are endogenously determined in the model. The model allows the computation of producer and consumer surplus as well as tax revenue, the sum of which serves as an approximate measure of sector-level welfare.[4]

[1] Steam coal includes all hard coal that is not coking coal (used for steel production), as well as sub-bituminous brown coal (IEA/OECD 2013). It is mainly used for electricity generation and has by far the largest share in global extraction across the different types of coal.

[2] A debate about constraints on coal exports in the interest of climate change mitigation is nascent in Australia, but to date has not been underpinned by quantitative analyses. See for instance, Peter Christoff (http://theconversation.com/why-australia-must-stop-exporting-coal-9698) and Brett Parris (http://theconversation.com/expanding-coal-exports-is-bad-news-for-australia-and-the-world-17937). A tax review proposed a resource rent tax including coal (Commonwealth of Australia 2010), which was legislated in 2012 but repealed in 2014. Relatedly, Martin (2014) suggests a coal-export safeguard regime to ensure that trade only occurs with partners that offset related CO_2 emissions.

[3] Recently, the literature on international steam coal markets gained some attention. In the tradition of Kolstad and Abbey (1984), two numerical equilibrium models of the international steam coal market have been developed: COALMOD-WORLD, which we further develop in this paper, and one model by Paulus and Trüby (2011) and Trüby and Paulus (2012).

[4] This welfare measure does not represent any economy-wide effects that flow from changed prices and resource allocations within an economy.

This paper contributes, first and foremost, to the literature on supply-side climate policy initiated by Sinn (2008) who points out the problem of a *green paradox*.[5] Accordingly, climate policy should tackle the supply side in order to slow down the extraction path of fossil fuels and to incentivise the conservation of carbon in the ground. Harstad (2012) analytically investigates a compensation scheme for resource-rich countries through a market for extraction rights. Committing to conserve coal deposits in situ, a climate coalition can cost-efficiently reduce emissions; resource owners in turn generate revenues by selling extraction rights. Hoel (2013) finds that preventing the extraction of the most expensive reserves reduces overall emissions and does not provoke a *green paradox*. Collier and Venables (2014) finally extend the Harstad (2012) idea by focussing on coalition enforcement through moral pressure and a ring-fence cap-and-trade system, where oil resource owners compensate owners of coal deposits to leave the coal in the ground.

In contrast to these proposed compensation mechanisms for reduced extraction, we focus on the complementarity of rent capturing and climate change mitigation, hence, on the self-interest of restricting supply[6]: Levying coal taxes, generates, on the one hand, revenues against the background of improved terms-of-trade—a motive for trade policy well-known from the literature. On the other hand, an export tax reduces global coal consumption and, hence, CO_2 emissions.

Our contribution is thereby complementary to Fæhn et al. (2017) who focus on resource-rich Norway. While examining the crude oil market, they find that the largest contribution to meet CO_2 reduction targets should be made by withholding oil extraction. In contrast to Fæhn et al. (2017), we rely on a detailed representation of the supply side (of steam coal) including capacity constraints and trade costs. Supply curves are, hence, endogenously derived rather than determined by assumptions on long-term supply price elasticities.

Finally, this paper is related to the literature on the interaction between climate policy and strategic behaviour. This literature focuses on demand-side climate policy in the presence of a supply-side cartel, like OPEC (cf. Liski and Tahvonen 2004; Johansson et al. 2009; Böhringer et al. 2014), while we, in contrast, analyse coal taxes levied by a coalition of export countries or a ‘grand coalition’ of all coal-producing countries, hence, coordinated supply-side climate policy.

The remainder of this paper is organised as follows. Section 2 explains the model specification and describes the analysed scenarios. In Section 3, we present and discuss numerical results, while Section 4 concludes and details implications for supply-side climate policy.

2 Model

2.1 Model specification and solution algorithm

For our analysis, we rely on a multi-period partial equilibrium model of the international steam coal market.[7] It is based on a stylised representation of different market agents along the value

[5] See Lazarus et al. (2015) as well as Collins and Mendelevitch (2015) for up-to-date overviews of the research on supply-side climate policy.

[6] Kalkuhl and Brecha (2013) speak of *climate rents*, which are created by the climate policy-induced scarcity of remaining CO_2 emissions. In this context, Eisenack et al. (2012) find that—depending on the allocation rule—a global carbon cap may leave resource owners better off compared to a business-as-usual.

[7] The Electronic Supplementary Materials (ESM) contain the complete mathematical formulation of the model for the case of coal taxes—both on production and on exports-only—as well as a list of all endogenous variables and parameters.

chain of steam coal including extraction and international trade. These market agents are assumed to maximise profits under operational and technical constraints, such as production or transportation capacity restrictions. Infrastructure investments are endogenously determined, where investment costs are weighted against future streams of revenues. Consumption of steam coal is represented by inverse demand functions. The price sensitivity of the supply side, in contrast, is endogenously determined and crucially depends on production and transportation costs and infrastructure constraints. While we represent the international steam coal market as being competitive, we assume that governments of major exporting countries may well affect international coal prices, similar to Kolstad and Abbey (1984) and Kolstad and Wolak (1985).

In our default formulation, we embed this model as the lower level in a two-level game, where at the upper-level policy makers maximise tax revenues by levying coal taxes on exports or production (cf. Kolstad and Abbey 1984). We model coal taxes based on the energy content of assessed volumes; they are, hence, proportional to carbon taxes. While the policy maker anticipates the reaction of market participants—and hence the impact on prices and quantities in equilibrium—affected market agents take the tax rate parametrically in their decision process.[8] Mathematically, this two-level game constitutes a *Mathematical Program with Equilibrium Constraints* (*MPEC*).[9] As solution techniques applied to large-scale models are still in a development stage (cf. Siddiqui 2011; Gabriel and Leuthold 2010), we combine and test different methods in order to robustly solve the outlined problem (see the ESM for more details).

Alternative to revenue-maximising tax rates, we additionally apply the model for a broad spectrum of exogenously given tax rates.

2.2 Data description and scenario definitions

Our detailed dataset represents all major steam coal-producing and steam coal-consuming countries covering 95% of world coal production in the base year 2010. Some countries are further disaggregated into separated geographical regions in order to allow for within-country heterogeneity in resource deposits and transportation costs to consumption areas. Overall, we include 25 production and 40 consumption regions as well as 16 export harbours.[10] The underlying dataset is collected from various sources and described in detail in Holz et al. (2015, 2016). The model solves in five-years steps. For the calculation of cumulative and average values, we rely on a linear interpolation between the model periods. All cumulative values that we present in the following are calculated for the period 2015 to 2035.

[8] This Stackelberg-leader-follower relation is a common assumption in the literature (cf. Eisenack et al. 2012) and requires the existence of a credible commitment of the respective policy maker (cf. Brander and Spencer 1985).
[9] Numerical applications of MPECs can be found in a wide range of disciplines and research questions. In contrast to analyses of market power with similar players on both the upper and lower level (cf. Siddiqui and Gabriel 2013; Trüby 2013; Gabriel and Leuthold 2010), our framework allows for the analysis of economic policy decisions given the reaction of market participants. Similar applications include Matar et al. (2015) on optimal investment credits to increase energy efficiency and reduce oil consumption in Saudi-Arabia, Bard et al. (2000)on the optimal incentive to encourage the production of biomass, Labbé et al. (1998) on the optimal toll setting for a road network, and Scaparra and Church (2008) on the cost-efficient way to protect a service system from being disrupted by saboteurs or terrorists. To the best of our knowledge, our study is the first that numerically analyses a supply-side climate policy implementation (at the upper level) on an international fossil fuel market (at the lower level).
[10] A complete list of nodes can be found in the ESM.

We construct our *Base Case* in line with the *New Policies Scenario* (*NPS*) of the *World Energy Outlook* (WEO, IEA/OECD 2012a). The *NPS* is a scenario of moderate climate policy, assuming the implementation of current climate policy proposals. Global emissions are on an increasing path with global steam coal consumption being projected to rise through 2035. While we base our reference coal consumption levels on IEA (IEA/OECD 2012a, b), the patterns of production and international trade flows are endogenously determined in the model representing profit-maximising firm behaviour.

We construct a variety of coal tax scenarios. We start with two scenarios that rely on the imposition of coal taxes on exports but differ in the countries that levy the tax. The first scenario (*Tax AUS*) focuses on a unilateral export tax on steam coal levied by Australia, a large exporter of steam coal with a share in international trade of about 20% in 2015 (cf. IEA/OECD 2016b). The second scenario (*Tax Coalition*) analyses the situation of a co-ordinately set export tax by a coalition of major exporting countries, namely Australia, Indonesia, Colombia, and South Africa that had a joint share in international traded steam coal of 73% in 2015 (cf. IEA/OECD 2016b).

We then consider alternatives to these two main scenarios. First, we compare the levy of export taxes with the case of taxes levied on the entire production of coal. Second, we calculate revenue-maximising export and production taxes for grand coalitions of all exporters[11] and all producers, respectively. Third, we investigate the case of a common tax rate of 10 USD/tCO_2 across all scenarios. Finally, and in order to evaluate the induced CO_2 emissions reductions in our different scenarios, we run a scenario (2 °C) with coal consumption consistent with a 2 °C target based on the *WEO 450 ppm scenario* (IEA/OECD 2012a).

As our default, we assume a private discount rate of 10% along the value chain, a government discount rate on tax revenues of 5%, and a moderate annual tax growth rate of 2.5%. For all scenario runs, we assume the introduction of the scenario-specific coal tax in the model period 2015. We rule out anticipation by any model agent by not allowing for adjusted infrastructure expansions prior to the implementation of the coal tax. This helps to avoid any inconsistencies.

3 Results

3.1 Export taxes on coal

Levying an export tax on coal leads to different partial effects. First, coal extraction and exports from the tax-implementing country are reduced, potentially accompanied by an increase in world coal prices (the terms-of-trade effect). Second, since exporting gets relatively more expensive due to the additional costs incurred by the export tax, supply to domestic consumers is encouraged; consumption in the tax-setting country, thus, rises. Finally, production in all other countries may increase. Export competitors compensate for the lower international supply, while net importers rely on domestic production to a larger extent. Note that this rebound effect is a specific form of carbon leakage different to the well-established energy market channel (cf. Burniaux and Oliveira Martins 2012).

[11] The exporters' grand coalition consists of Australia, Colombia, Mozambique, Indonesia, Poland, Russia, South Africa, Ukraine, the USA, and Venezuela.

It is an increase in the supply in non-regulating countries incentivised by rising prices that increases emissions, rather than increased consumption due to lower prices. Overall, and depending on the rebound effects, global CO_2 emissions from coal use are reduced.[12]

3.1.1 Scenario Tax AUS: a unilateral Australian export tax on coal

Our model results show that Australia could generate up to 16 billion USD of (discounted) tax revenues until 2035 by unilaterally levying an export tax on coal of initially 6.7 USD/tCO_2.[13] Given the Australian coal quality, this is equivalent to around 18 USD/t of Australian steam coal, while, by comparison, average prices for coal exported from Australia were between 80 USD/t and 100 USD/t in the period May 2014 to September 2016 (IEA/OECD 2016c). At this tax level, producer surplus is reduced by 44%, while total sector level welfare (including producer surplus, consumer surplus, and tax revenue) increases by on average 10.7 USD/tCO_2 avoided.

Such a policy induces shifts in Australian and worldwide consumption and production patterns (see Fig. 1, left) leading to a significant rebound effect of 73.3%—on average across years.[14] Only at the time the tax is implemented, exporting competitors and importing countries are not able to rapidly expand their supply as most of them already run at capacity. With expanded capacities, particularly China and India replace import demand by domestic production, which gains a comparative advantage in the long run. Similarly, the international export competitors Indonesia and Russia increase exports by shifting supply from the domestic to the international market. In contrast, the USA, Colombia, and South Africa cannot competitively increase their exports significantly, partly due the long distances to the main destinations of Australian coal in Asia.

With an increase of 4% in 2015, the price increase is the strongest, when the market cannot completely adjust to the tax shock. By contrast, there is hardly any price change in the periods after 2015.

In line with coal consumption, global CO_2 emissions are lower than in the *Base Case*, despite the increase in emissions in Australia. Globally, annual emissions from coal use decrease by up to 63 MtCO_2, on average by 36 MtCO_2 annually, if Australia imposes a unilateral export tax. While this is small relative to global emissions, it corresponds to a 9% reduction of GHG emissions (CO_2e) from Australian energy usage in 2015 (DEE 2016).[15]

[12] Note that we only indirectly account for substitution with other fossil fuels through inverse demand functions. A relative price increase in coal, e.g. through coal taxes, could partly ramp up the consumption of natural gas and crude oil, leading to increased emissions from these sources. Nevertheless, since coal is the most carbon-intensive fossil fuel, global emissions would likely decline.

[13] Additional figures and tables are provided in the ESM. There, we also present guiding *Base Case* results.

[14] Note that this rebound effect is expressed on a country-basis, i.e. 73.3% of reduced Australian emissions from production are compensated by other producers. The rebound effect would be even higher (75.9%) when expressed on a policy-basis, i.e. how much of Australian emissions from export supply are compensated making the shift to domestic consumers explicit. The two types of carbon leakage only differ for coal taxes on exports while they coincide for coal taxes on the entire production.

[15] To put this reduction into perspective, note the recent closure of a large lignite power plant which emitted around 15 MtCO_2 per year is expected to reduce emissions by 5 MtCO_2 per year in the short term (Jotzo and Mazouz 2015) and more in the long term.

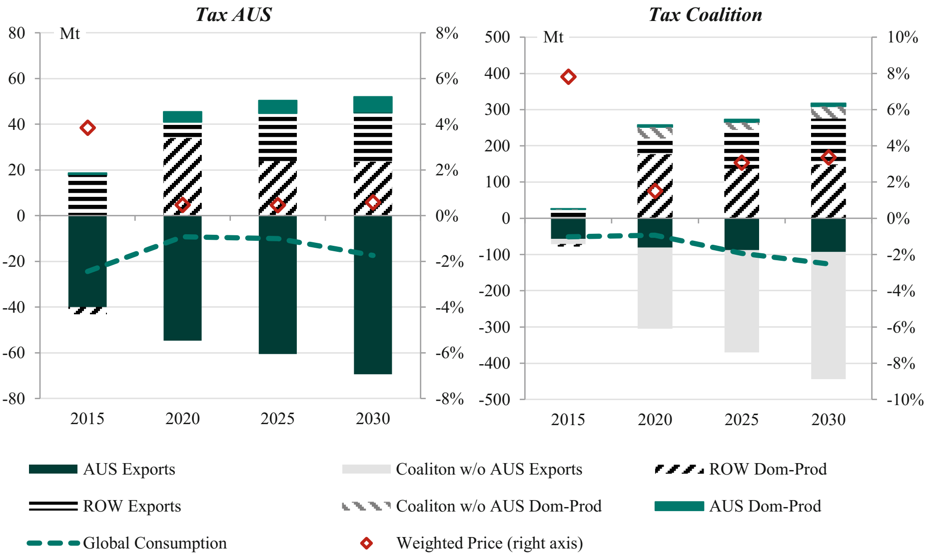

Fig. 1 *Export tax*: decomposed impact of the revenue-maximising export tax on quantities, in Mt, and change in weighted CIF prices in percentages (right axis) relative to the *Base Case*, for Australia only (*Tax AUS*, left) and the *Tax Coalition* (right)

3.1.2 Scenario Tax Coalition: a joint export tax on coal levied by major exporting countries

A coordinated export tax by the four major exporting countries Indonesia, Australia, South Africa, and Colombia leads to a stronger terms-of-trade effect and higher tax revenues compared to any unilateral policy action.[16] Joint (discounted) tax revenues could reach up to 125 billion USD over the next 20 years (see Fig. 2, left) The common revenue-maximising tax level is 10.1 USD/tCO_2, which is approximately 22–26 USD/t on exported steam coal, depending on the carbon content of coal that differs across producers. Compare to the unilateral case, Australian producer surplus is even lower (−55% compared to *Base Case*). By contrast, average total sector level welfare gains increase to a level of 15.5 USD/tCO_2 avoided.

At this tax level, global seaborne trade of coal is reduced by 20% while the coalition restrains about 40% of its exports. As in *Tax AUS* the rebound effect is mainly driven by a pronounced increase in domestic production in importing countries like in China, while exporting countries cannot compensate significantly for the supply restrictions of the major four exporters.[17] The average coal price increase is most pronounced in the year of the tax introduction (with 8% see Fig. 1, right), while over time it is moderate at 3%.

[16] We test the sensitivity of the results to the members of the coalition by adding the USA (see the ESM). We find a substantial increase in tax revenues and CO_2 emission reductions, while the US share in additional revenue is small.

[17] With 74.7% the rebound effect is even larger than in the *Tax AUS* scenario. This can be explained by characteristics of the new coalition members South Africa and Colombia. While both exporters do not compensate in *Tax AUS* due to capacity restrictions, it is their reduced supply in the *Tax Coalition* scenario that is (partly) compensated by (mainly) India and China.

Overall, global consumption is reduced to a much larger extent than in the unilateral Australian export tax case. On average, global CO_2 emissions from coal are reduced by 194 $MtCO_2$ annually, compared to annual reductions of 36 $MtCO_2$ in the unilateral case.

3.2 Production taxes on coal

While export taxes lead to net reductions of global CO_2 emissions, they cause trade diversion and economic inefficiencies as coal consumption is shifted to domestic consumers in tax-setting countries. By increasing the tax base, production taxes are less distortive and may be more effective in reducing emissions.

A tax levied on the entire production of the main exporters as contained in *Tax Coalition* is a major intervention in the cost structure of the global steam coal market as it affects 17% of global production in the base year.

Fig. 2 (right) shows how global emissions decline in the production tax level and decomposes tax revenues across members. We find that the revenue-maximising production tax rate exceeds the coalition's export tax by 20%, reaching 12.2 USD/tCO_2. At this level, the coalition's total (discounted) tax revenues reach 266 billion USD—twice the amount as with taxes on exports only—while South Africa, with its high and increasing domestic coal demand, has a dominate role in the coalition, with almost 50% of the coalition's revenue (compared to 15% in the export tax scenario).

Here, tax revenue is generated from payments of both domestic and foreign consumers. Accordingly, emission reductions are more pronounced as both the coalition's exports and consumption levels decline. Accounting for the rebound effect, global CO_2 emissions are reduced by almost 8.5 Gt until 2035.

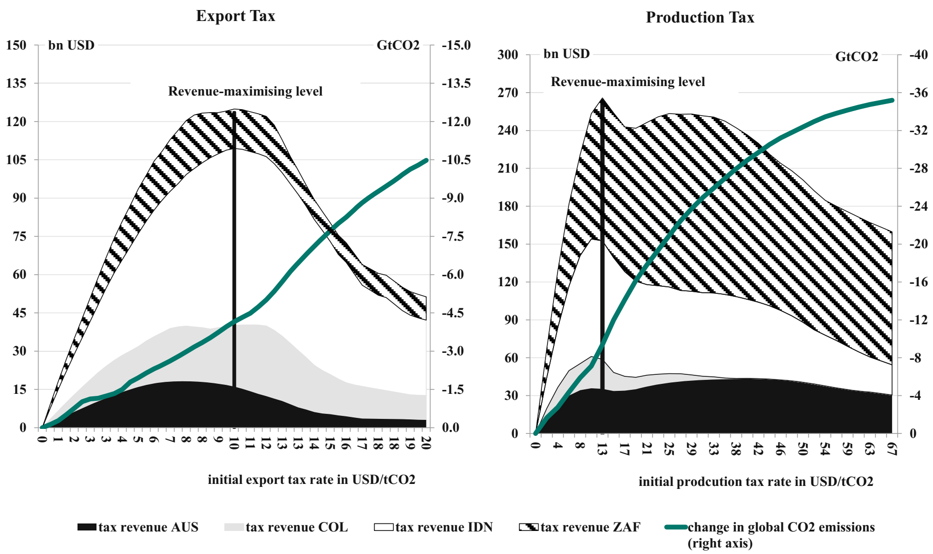

Fig. 2 *Tax Coalition:* tax revenues of the coalition's members, in billion USD, and change in cumulative global CO_2 emissions from coal use, in Gt (right axis), as a function of the initial common tax rate, in USD/tCO_2, implemented as export tax (left) and as production tax (right)

3.3 Comparison

Table 1 summarises key results on tax revenue, production, trade, prices, and CO_2 emissions across all different scenarios.

For the *Tax AUS* and *Tax Coalition* scenarios (Table 1; upper panel), we find revenue-maximising tax levels within a range between 6.7 and 12.2 USD/tCO_2, while on average steam coal-related emissions could be reduced between 37 MtCO_2 to 423 MtCO_2, annually. The production tax scenarios consistently show higher revenue-maximising tax levels and CO_2 emission reductions.

While carbon leakage rates are consistently lower compared to their export tax counterparts, Table 1 reveals a non-monotonous relationship between leakage rates and number of taxing countries, which might seem counter-intuitive at first. However, the calculated leakage is the sum of countervailing partial effects: one leads to a declining leakage rate in the number of coalition members (as every additional member is not free-riding and compensating for reduced supply anymore). But leakage also depends on the importing countries' ability to substitute reduced imports from the taxing countries, either by increasing domestic supply (which is the case especially for China) or by sourcing from other suppliers that are able to increase their exports. In case the coalition is extended to counties that do not contribute to leakage even if not part of the coalition, leakage might increase with increasing coalition size.

Table 1 additionally presents results of the 2 °C scenario and the grand coalition scenarios. The analysis reveals that a consumption pattern that is consistent with 2 °C (i.e. with an average CO_2 emission reductions from coal usage of 4.0 GtCO_2/a) is neither achieved by an export tax (1.2 GtCO_2/a) nor by a production tax levied by all coal exporting countries only (2.6 GtCO_2/a)—at the tax revenue maximising rates. It is only when a global regime of coal production taxes is implemented that the level is clearly exceeded (7.6 GtCO_2/a). It is worth pointing out that the supply-side policies lead to strong price increases (16–112%), while in the case of global demand-side-driven reduction in steam coal consumption, prices decrease by on average 17%.

In all scenarios, emission reductions coincide with a net sector level welfare gain for the tax setters per tCO_2 avoided. The average gain is higher in the export tax than in the production tax cases. Due to the simultaneous effects of increasing domestic consumer surplus (in case of an export tax), decreasing domestic producer surplus, and generating tax revenue, the relationship between coalition size and net welfare gains is not monotonous. The relationship is determined by the complex interplay of the endogenous supply function, trade patterns, and composition of domestic versus export supply.

Finally, we compare results for all scenarios using a common tax rate on coal of 10 USD/tCO_2 (Table 1; lower panel). Doing so, we can properly highlight the difference in the size of the coalition (ranging from one country only to grand coalitions) and between coal taxes on exports and the entire production. For instance, if a coalition of major coal exporters set an export tax, then reductions in CO_2 emissions from coal use are five times larger than if Australia as a major exporter acted alone. Moreover, if all coal-producing countries implemented this moderate tax rate of 10 USD/tCO_2, global emissions from coal could be reduced by almost 2 GtCO_2, annually—a significant contribution to climate change mitigation.

Table 1 Comparison of key statistics across scenarios for at the tax-revenue maximising level, and at 10 USD/t as the initial tax rate

Scenario	Revenue-maximising initial tax level [USD/tCO_2]	NPV of tax revenue 2015–2035 [bn. USD]	Average reduction in production of tax setting countries [Mt/a]*	Average reduction in global production [Mt/a]*	Reduction in global production 2015–2035 [%]*	Reduction in seaborne trade [%]*	Average price change [%]*	Average emissions reduction 2015–2035 [GtCO_2/a]*	Leakage rate; CO_2-based [%]	Average sector level welfare*** gain per emission reduction for tax setters [USD/tCO_2]
Revenue-max. tax										
Tax AUS										
Export tax	6.7	16	52	12	0.2	3.2	0.8	0.04	73.3	11.7
Production tax**	8.8	32	77	26	0.4	4.0	1.5	0.07	63.5	2.9
Tax coalition										
Export tax	10.1	125	311	84	1.4	20.3	3.2	0.19	74.7	15.5
Production tax	12.2	266	426	180	3.0	22.4	6.4	0.42	59.4	5.0
Grand tax coalitions										
All exporters + export tax	42.6	344	567	513	8.6	74.9	15.8	1.22	35.9	10.6
All exporters + production tax	26.0	858	1428	1098	18.5	55.1	34.4	2.63	23.9	12.5
All producers + production tax	40.5	3634	3095	3095	52.3	50.1	111.6	7.61	0	9.2
2 °C scenario	n.a	n.a			27.3	30.8	−17	4.0		
Common 10 USD/tCO_2 tax										
Tax AUS										
Export tax	n.a	11	91	24	0.4	5	1.6	0.07	70.1	2.4
Production tax	n.a	32	99	33	0.5	4.9	2.0	0.10	63.2	0.1
Tax coalition										
Export tax	n.a	125	308	83	1.4	20.1	3.2	0.19	74.7	15.6
Production tax	n.a	253	340	142	2.4	17.4	5.0	0.37	59.7	8.2
Grand tax coalitions										
All exporters + export tax	n.a	211	200	164	2.7	40.8	6.2	0.35	66.7	21.4
All exporters + production tax	n.a	569	675	407	6.8	29.1	13.5	0.96	41.9	20.0
All producers + production tax	n.a	1635	777	777	13.1	9.8	26.5	1.90	0	28.4

*Relative to the Base Case

**Revenue-maximising level with constraint of positive export quantity

***Welfare is defined here as the sum of producer surplus, consumer surplus and tax revenue

4 Conclusions and implications for supply-side climate policy

This paper analyses the case for coal taxes as supply-side climate policy. We investigate to what extent large coal exporting countries can help to achieve global climate change mitigation, while at the same time benefitting from tax revenues against the background of improved terms-of-trade. To this end, we construct and numerically apply a multi-period equilibrium model of the international steam coal market. We analyse how restrictions of coal supply impact the international coal market through reactions of competing exporters and importing countries and to what extent they can reduce global CO_2 emissions from coal consumption.

Our numerical modelling of coal export and production taxes suggests that supply-side policy for coal can be effective in climate change mitigation and, at the same time, be in the self-interest of coal producing countries.

A large coal exporter like Australia could realise a net welfare gain by imposing a unilateral export tax. Substantial tax revenue, and in the case of an export tax, gains from access to cheap coal for domestic consumers overcompensate a fall in profits for suppliers,[18] where the quantity effect dominates the price effect. At the same time, there would be a strong compensatory effect in world coal markets by increased production from competing exporters and increased domestic production in importing countries like India and China. The net global emissions reduction is significant (relative to Australian emissions) in the short run but almost non-existent in the long run as other producers invest in production and export capacity and fill the gap. Hence, unilateral supply-side climate policy in the coal market would have a very limited effect on global coal prices, coal use, and carbon dioxide emissions, while Australia would see reductions in exports.

In contrast, a coalition of the major exporters of steam coal all levying a coal export tax—in our scenario Indonesia, Australia, Colombia, and South Africa—could have a significant effect on global coal markets and, thus, global CO_2 emissions. Our results suggest that at the revenue-maximising level of about 10 USD/tCO_2, CO_2 emissions from steam coal would be reduced by on average 190 Mt annually, or 2% of current total emissions from coal use in the power sector (IEA/OECD 2015). The coalition of coal-taxing countries would benefit from higher coal export prices and experience a higher welfare gain.

International trade law and the possibility of retaliatory trade action by importing countries speak against the introduction of such export taxes and the formation of a cartel of major exporters. Moreover, the domestic effects of an export tax are ambiguous: it means cheaper coal domestically which benefits coal-using industries, but it also means economic distortions in relation to other energy sources and it entails greater domestic carbon emissions and local pollution. A production-based tax may not face the same difficulties and avoids market distorting effects of shifts to domestic consumption because domestic supply and traded coal become more expensive alike. Revenue-maximising rates for coal production taxes are higher than for export taxes, and the effects on global CO_2 emissions are greater than for export-only taxes. For instance, if the same group of major exporters imposed a tax on production rather than exports, our modelling suggests that global emissions reductions could be increased by more than twice to 420 Mt per year, while the net welfare effect is still positive but smaller.

[18] Setting these results in perspective, this reduction corresponds to reduced profits for marginal suppliers (or even losses in the case of long-term contracts, or stranded infrastructure investments), while local infra-marginal suppliers could be net benefiters of increased prices. This is in contrast to a demand-side policy, which depresses prices and puts all producers at a disadvantage.

It is a globally levied tax on all coal production—not just the production of the major exporters—that would have the greatest effect. Even a moderate tax rate of 10 USD/tCO_2 on production could significantly reduce annual emissions from coal use, in our modelling by 1.9 GtCO_2 or over 19% of current global emissions from coal use in the power sector (IEA/OECD 2015).

The implications of our numerical modelling for supply-side climate policy for coal are clear: effectiveness requires broad participation and ideally a tax on all coal production not just exports. Only then and at a significant level of the tax rate would it be possible to achieve global emission reductions form coal usage that are consistent with the 2 °C target.

Supply constraints by fossil fuel exporters, nevertheless, may hold promise as part of a broader climate policy strategy. They can leave the owners of fossil fuel reserves better off, in contrast to the conventional policy approach of tackling the demand side through improved terms of trade (implying a shift in economic rents from importing countries) and higher tax revenue, yet with reduced coal industry returns and less economic activity in coal mining. Feasibility of such a policy would critically hinge on political economy factors.

We have applied a comprehensive tool to analyse the global steam coal market at a disaggregated level. However, we do not investigate the external stability of the analysed coal tax coalition, the distribution of rents among countries agreeing on joint coal taxes and between different interest groups, the use of coal tax revenues, and broader economic effects of lower coal production and higher coal prices. Questions remain whether a coal tax, even if economically beneficial, would indeed be favoured in different coal-exporting countries and how various options for revenue recycling, such as a potentially welfare-enhancing tax reform or redistribution, may increase its support. Moreover, our partial equilibrium framework does not allow for the evaluation of economy-wide effects on production, consumption, and investment that would be brought about by coal taxes. Further analyses could also explore the induced shift to other fuels and its impact on CO_2 emissions in order to gain a more holistic view on the role that coal taxes could play as supply-side climate policy.

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