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Emission Trading with Fiscal Externalities: The Case for a Common Carbon Tax for the Non-ETS Emissions in the EU

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Abstract A government is fiscally constrained if it is unable to raise sufficient tax revenue to finance the first-best level of public spending. When involved in emission trading, a fiscally constrained government will potentially seek to close its fiscal gap through emission permit sales. This fiscal incentive therefore generates a fiscal externality in the permit market that is endogenous to the extent of fiscal constrainedness among the participating countries. Our theory explains how, and when, fiscal externalities may be expected to arise. Moreover, we show that in a permit market equilibrium with fiscal externalities, the initial allocation of emission permits between countries will affect: (1) the price of emission permits, (2) the global distribution of abatement effort, and (3) total greenhouse gas mitigation costs. This is contrary to the textbook model of emission permit markets. Our findings are especially relevant for the EU which is about to allow for trading in emission rights between EU member countries for all emissions outside the European Emissions Trading System.

Keywords Emission permit trade · Fiscal constraints · Fiscal incentive · Carbon tax

1 Introduction

By the end of 2015, the UN climate negotiations ended with a treaty in Paris. As part of this treaty the EU has committed to reduce total greenhouse gas (GHG) emissions from EU territory with 40% by 2030, compared to 1990 levels. To reach this target, the EU will reduce the amount of available emission permits in the European Emissions Trading System (ETS). In addition, the EU has decided to allow member countries to trade emission rights also within those sectors that are not covered by the ETS, which amounts to about 60% of total EU emissions. The properties of this type of dual system, where some of the emission trading

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is delegated to the market but where a substantial part is directly (or indirectly) controlled by governments, is the main focus of our analysis.

Emission trading as a part of an international agreement on climate change is said to be characterized by two favorable features. First, it minimizes mitigation costs for any given total emission reduction target, a result which dates back to the literature on the optimal regulation of environmental pollutants (Dales 1968). Second, the emission reduction contributions of countries can be set according to their level of income without impeding efficiency (Montgomery 1972). This is precisely the route the EU has followed when allocating emission reduction obligations between member states for non-EU ETS emissions (see European Commission 2016a, b).

However, as with any type of international trade, emission trading that can be controlled by governments may introduce a *fiscal incentive* that may hamper the simple textbook notion of efficiency. We demonstrate that the fiscal incentive is triggered when national governments are *fiscally constrained*—that is, when they are unable to raise sufficient tax revenue to finance their first-best preferred levels of public spending. A fiscally constrained government has the incentive to close its fiscal gap through the use of any available instrument, including manipulating emission trade flows. The fiscal incentive therefore generates a fiscal externality in the permit market that is endogenous to the extent of fiscal constrainedness among the participating countries.

Analyzing a permit market equilibrium with fiscal externalities and where governments act as social welfare maximizers, we demonstrate that the resulting market equilibrium is constrained efficient—constrained by the given fiscal constraints and the permit market institution, and efficient in the sense that welfare is maximized subject to these constraints. However, in a permit market equilibrium with fiscal externalities, total GHG abatement costs, defined as losses in production, are no longer minimized. This result echoes existing insights from the literature on fiscal externalities in permit markets, except that we add on this literature by identifying fiscal constrainedness as a fundamental source of externalities. Furthermore, in a permit market with fiscal externalities, the initial allocation of emission reduction plans will affect both the price on emission permits and the distribution of GHG mitigation effort between countries—a result that stands in sharp contrast to the standard textbook result.

Our finding that permit markets may create fiscal externalities also implies that welfare may be improved by changing the GHG abatement institution from cap-and-trade to a common carbon tax coupled with a redistribution scheme for the tax revenue. The climate agreement members then have two instruments to tackle the two externalities: The tax to deal with the emission externality, and the revenue from the tax to increase public goods provision in fiscally constrained countries. The common carbon tax thus eliminates the fiscal externality, and the same emission target can be reached at lower total costs to the economy.

That countries may be fiscally constrained is by now well established in the economics literature. Cukierman et al. (1992) make a distinction between fiscal policy and a tax reform. Fiscal policy is the choice of tax rates and the level of government spending. A tax reform is the broad design of a tax system which involves both the available tax base and the technology for collecting taxes. While fiscal policy can be changed from year to year, a tax reform takes several years, and thus, fiscal policy in any country can be constrained in the short run. Besley and Persson (2011) formalize the distinction between fiscal policy and tax reforms by assuming that the government cannot collect more than a given share of private income as taxes in a given year. Moreover, a country is fiscally constrained if the government could have improved social welfare by collecting a higher share of private income.

Countries may be temporarily fiscally constrained. This is especially relevant for the EU which was severely hit by the financial crisis in 2008. For the period 1990–2008, Bacchiocchi et al. (2011) find that EU countries with high public debt were fiscally constrained with respect to investing in public goods. Their situation likely worsened after the financial crisis hit in 2008.[1] Furthermore, at any given level of fiscal capacity, a government may become temporarily fiscally constrained if there is a positive shock to the marginal social benefit of public funds. Economists and economic historians have extensively analyzed how both intrastate and interstate conflicts, or wars, suddenly and significantly increase the fiscal needs of countries, often beyond their current fiscal capacities.[2] In the current geopolitical situation—with the increased tension between EU and Russia and the demand from the U.S. administration that several EU countries should increase their military spending to comply with the North Atlantic Treaty Organization (NATO) target of 2% of GDP—this is also relevant for the EU.

In order to allow for high ambitions in the countries' mitigation efforts, the Paris treaty also recognizes trade in emission reductions between countries (UN 2015, Article 6). Thus, the mechanism we explore in the paper may be relevant for a larger setting than the EU in the not so distant future. The fiscal stance in many developing countries may serve as an example of fiscal constrainedness. It is well documented that the lack of an effective technology for collecting taxes prevents several developing-country governments from raising the amount of government funds needed for the financing of a socially desirable level of public goods spending, such as spending on basic health and schooling services, or on economically sound public infrastructure investments.[3] Additionally, the use of advanced transfer pricing techniques by large multinational companies, and organizational issues at the lower bureaucratic level, including corrupt practices, severely limit the fiscal capacity in many of these countries. According to a joint report by the IMF, OECD, UN, and WB, "[…] half of sub-Saharan African countries still mobilize less than 17% of their GDP in tax revenues […]".[4] Existing evidence from the trade and tariffs literature suggest that fiscally constrained governments are both willing and able to distort trade for the purpose of closing their fiscal gaps. For example, Baunsgaard and Keen (2010) show that fiscally constrained governments in low-income countries are significantly more likely than high-income governments to increase their trade tariffs above what is globally efficient, to boost their government revenues.[5]

Technically, the point of departure for our model setup is a general cap-and-trade model where we assume the existence of an international agreement on the overall cap on total GHG emissions. The overall cap is allocated to countries and, subject to this allocation,

[1] Notice that financial crises are even more critical for the ability to raise public funds and to optimally adjust fiscal policy among countries with a low level of fiscal capacity (World Bank 2009).

[2] See, e.g., Dincecco and Prado (2012), Dincecco and Katz (2012), Gennaioli and Voth (2011), Hintze (1906) and Tilly (1975, 1990).

[3] For a broad documentation of the weak fiscal capacity among developing countries, see UNDP (2011, Ch. 7). Indeed, Besley and Persson (2013) list as a stylized fact that, due to lack of effective tax technology and widespread tax evasion: "Rich countries collect much higher tax revenue than poor countries despite comparable statutory rates."

[4] See International Monetary Fund, Organization for Economic Cooperation and Development, Unit-ed Nations, and World Bank (2011). This report states that (p. 9) the identification of "ways to help developing countries tax Multinational Enterprises (MNEs) through effective transfer pricing" is one of five requests asked by the G-20 to help raise the fiscal capacity in developing countries. Khan (2006) discusses the relationship between fiscal capacity and corruption in developing countries.

[5] Specifically, Baunsgaard and Keen (2010) show that, among those countries that actually do liberalize trade by reducing their tariffs, the high income countries more quickly develop alternative sources of government revenue while the low income countries do not, suggesting that the low income countries are on average more fiscally constrained.

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national governments can freely set their national level of emissions. The difference between the national level of emissions and the emission permit allocation can then be traded on the international market, as in the non-EU ETS trading system. The benevolent governments in our model ultimately care about household welfare, which derives from the households' consumption of both private and public goods. Households, in turn, derive income from production with GHG as a by-product, and national governments finance public goods provision through taxing household income and, potentially, from trading in emission permits.

If all governments are free to raise whatever amount of funds they desire through taxation, fiscal policy, on one hand, and the abatement policy, on the other hand, are effectively separated in the governments' welfare-maximization problem. In this scenario, the equilibrium level of public spending coincides with the first-best preferred level, and the government optimally sets the national emission level such that the marginal industrial cost of abatement is equal to the equilibrium price of emission permits. In the more realistic event that some governments are fiscally constrained, however, the optimally chosen levels of emissions in these countries are also influenced by their respective marginal utilities of public goods provision. In market equilibrium, the fiscal incentive of those countries that are fiscally constrained will be transmitted to *all* participating countries through the equilibrium price of emission permits. Hence, even the abatement levels of fiscally unconstrained countries will be affected, and the permit market equilibrium is no longer cost efficient, that is, total GHG abatement costs are no longer minimized.

As an extension, we also discuss how emission trading may carry with it adverse dynamic effects. First, since access to the permit market effectively equips fiscally constrained countries with a powerful fiscal instrument, their incentive to invest in improving their ability to collect taxes will be weakened. Then, if different dimensions of state capacities act as strategic complements (as in, e.g., Besley and Persson 2011), economic development may be hampered. Second, the permit price in fiscally unconstrained countries will be lower than the social cost of carbon which, in turn, may provide too weak incentives for research and development (R&D) of new pollution abatement technology.

The remainder of the paper is organized as follows. In Sect. 2 we discuss our contribution in light of other related literature. Section 3 describes the model and the economic environment. In Sect. 4, we analyze the incentives of fiscally unconstrained and fiscally constrained countries, and derive the comparative statics. The non-EU ETS market equilibrium is analyzed in Sect. 5. In Sect. 6 we compare the non-EU ETS cap-and-trade regime with a common carbon tax. Section 7 includes a number of extensions. Finally, Sect. 8 concludes.

2 Related Literature

Our paper relates most closely to the literature on fiscal externalities in the international market for emission permits. While most contributions in this literature either make *ad hoc* assumptions about the fiscal policy objective of the national governments (as in, e.g., Brechet and Peralta 2007, 2012), or study the interaction of specific taxes with the permit market (as in, e.g., Babiker et al. 2004; Yale 2008; Costantini et al. 2013)—often with the aim of analyzing tax rules that may correct distortions due to, for example, market power (as in, e.g., D'Amato et al. 2017), locational choices of multinational corporations' activities (as in, e.g., Fischer 2006), or direct taxation of emissions trading (Costantini et al. 2013)—we take a step back and demonstrate that fiscal externalities caused by a government's intervention are expected to arise only to the extent that governments find it in the best interest of its

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population to intervene. In our model, fiscal policy and its interaction with the permit market in a country arises endogenously, by the welfare maximization of a national social planner (a benevolent government). Hence, we do not need to make specific assumptions about the preferences of the governments or the market structures for fiscal externalities to arise in our model. For example, in our framework, a government would only be "firm-oriented" or "revenue-oriented" (as in, e.g., Brechet and Peralta 2007, 2012) as an endogenous response to its welfare maximization problem. We therefore complement the existing literature on fiscal externalities by identifying fiscal constrainedness and the associated fiscal incentive as a fundamental source of such externalities. We demonstrate that the exact form, direction and extent of the fiscal externality is generally a function of economic structures and market institutions.

We also relate to a larger literature on how market imperfections in emission trading may induce a suboptimal market allocation of abatement. One strand of the literature focuses on imperfectly competitive permit trade. In this literature, governments trade directly with each other, as in our base case, and can use their supply of permits to exercise market power, see for example Hagem and Westskog (1998, 2009).

Furthermore, there is a literature asking whether a cap-and-trade system will give the correct incentives for R&D of less expensive abatement technologies. Cian and Tavoni (2012) show that positive technology externalities provide an argument for restricting permit trade if governments lack other instruments to deal with the technology externality. We, too, find that the incentives for abatement technology R&D may be too weak in a permit trade system, not because technology externalities are not properly internalized (such externalities are not included in our model), but because the permit price signal may be too weak. Our mechanism is, hence, complementary to that in Cian and Tavoni (2012).

Another literature deals more specifically with the economic consequences of the Kyoto Protocol, including the possibility of permit trade between nations. However, this literature mainly explores the inefficiencies resulting from having an incomplete climate treaty, that is, only a subset of countries had a binding emission cap in the protocol (see, e.g., Barrett 1998; Weyant 1999; Springer 2003).

There is also a literature on the linking of national permit markets. In this literature, governments trade directly with each other, as in our base case, but unlike in our paper countries' allowances are considered endogenous. Both Helm (2003) and Carbone et al. (2009) focus on whether linking permit trade markets improves welfare in such a setting. None of the mentioned contributions, however, look at how fiscal policy consideration may affect permit trade.

Finally, our paper relates to the so-called "resource-curse" literature which informs us that when a country is endowed with a valuable and tradable resource, political incentives may distort economic policies and outcomes. In particular, such distortion may happen when democratic institutions are weak, or when there is a high degree of political instability (Robinson et al. 2006).[6] Translated into the context of cap and trade, insights from this literature suggest that a non-democratic government may choose to abate more than the technically cost-efficient level of abatement, for the political elite to enrich themselves or their partisans through selling emission permits on the world market. While we believe that these types of mechanisms may indeed be relevant and hamper efficiency in similar ways as the fiscal incentive does, we show, however, that one need not resort to political economy distortions of any kind for the fiscal incentive to hamper economic efficiency.

[6] See, e.g., van der Ploeg (2011) for a broad review of the resource-curse literature, and Morrison (2010) on foreign aid and its parallels with the resource curse.

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3 The Model

3.1 Preliminaries

Our point of departure is the EU, but to the extent that emission trading will happen between governments outside the EU in the future, the model could also be applied to other regions or to the world as a whole. Emissions from large point sources in the EU are regulated by the EU ETS. All firms participating in the ETS are allowed to trade in permits across borders without the interference of the EU nation states. The ETS covers approximately 40% of total GHG emissions in the EU. The remaining 60%, or the so-called non-ETS emissions, come from sectors such as transport, buildings, and agriculture. Reducing the emissions from the non-ETS sectors is the responsibility of the EU nation states. Each nation state is given a national cap for the non-ETS emissions, and is allowed to trade with other countries in order to fulfill their emission reduction obligations.[7]

We set up a stylized model of permit trading between the EU countries with n heterogenous countries denoted $i = 1, \ldots, n$. For each country, we separate between emission permits that can be traded freely among firms (ETS) and emission permits that must be traded between countries (non-ETS). Correspondingly, for each country i we separate between ETS GHG emissions, ε_i, and non-ETS GHG emissions, e_i.

We assume that there exists a cap on total emissions which is split into a cap on ETS emissions, $\bar{\epsilon}$, and a cap on non-ETS emissions, $\bar{E}$. Each country i's current level of emissions in the two sectors are ε_{i0} and e_{i0}, respectively. The real cost (to production) of emission reductions are given by $\psi^i(\varepsilon_i)$ and $C^i(e_i)$, which reflect the country's characteristics in the ETS and non-ETS sectors. Denoting the first derivatives of the cost functions by C_e and ψ_ε, and the second derivatives by C_{ee} and $\psi_{\varepsilon\varepsilon}$, we assume $\psi_e^i, C_e^i \leq 0$ and $\psi_{\varepsilon\varepsilon}^i, C_{ee}^i \geq 0$ (as in, e.g., Rubin 1996). Hence, abatement is costly, and increasingly so.

Finally, using the abatement cost functions of each country, we can define the total abatement cost function $C^G(E)$, which is the solution to the following problem:

$$\min_{\varepsilon_i, e_i} \left\{ \sum_i \psi^i(\varepsilon_i) + C^i(e_i \right\} \quad s.t. \ \sum_i \varepsilon_i \leq \bar{\epsilon} \sum_i e_i \leq \bar{E} \tag{1}$$

Note that this problem effectively separates into two sub-problems; one for the ETS sectors and one for the non-ETS sector.[8]

3.2 Households

Each country is populated by a large number of identical households, and their economies are administered by national, welfare maximizing governments. Households derive income from industrial production with GHG emissions as a necessary by-product. The level of industrial income in country i can be represented as

$$\pi^i(\varepsilon_i, e_i) = \bar{\pi}^i - \psi^i(\varepsilon_i) - \rho^{eq}\varepsilon_i - C^i(e_i). \tag{2}$$

[7] The actual number is 30% reduction compared to 2005-levels. The allocation between countries can be found here: https://ec.europa.eu/climate/policies/effort/proposal_en.

[8] The current EU arrangement of having two separate targets for the ETS and the non-ETS sectors are most likely not efficient, as marginal abatement cost will generally differ across the two schemes. However, it is beyond the scope of the current paper to analyze or explain why the EU have chosen to have separate targets.

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where $\bar{\pi}^i$ is the level of industrial income before any emission reductions, ρ^{eq} is the ETS equilibrium permit price, and $\rho^{eq}\varepsilon_i$ is payments for emission permits in the ETS.[9] Firms participating in the ETS minimize costs with respect to the emission level:

$$\min_{\varepsilon_i} \left\{ \psi^i(\varepsilon_i) + \rho^{eq}\varepsilon_i \right\}$$

from which we obtain the first-order condition

$$-\psi_\varepsilon^i = \rho^{eq}, \tag{3}$$

yielding the cost minimizing level of emissions for the ETS sector, ε_i^*. Since both ρ^{eq} and ε_i^* is beyond the control of the single governments, we may express household income as $\pi^i(e_i) = \hat{\pi}^i - C^i(e_i)$, where $\hat{\pi}^i = \bar{\pi}^i - \psi^i(\varepsilon_i^*) - \rho^{eq}\varepsilon_i^*$.

The income, $\pi^i(e_i)$, is taxed at the flat rate t_i. Assuming that households derive utility from consuming their net income, y^i, and that they also value public goods consumption, G^i, we can write the preferences of the households as

$$u^i\left(y^i(t_i, e_i), G^i\right) = w^i\left(y^i(t_i, e_i)\right) + h^i\left(G^i\right), \tag{4}$$

where

$$y^i(t_i, e_i) = (1 - t_i)\,\pi^i(e_i), \tag{5}$$

and where the Inada conditions apply to both $w^i(\cdot)$ and $h^i(\cdot)$.[10] Public goods, G, can be interpreted narrowly, as the governments' provision of goods and services, or more broadly, as the sum of all fiscal expenses including transfers and redistribution. What is important for our analysis and results, is that the shape of the $h(\cdot)$-function—which determines the marginal, social benefit (in terms of national welfare) of public funds at different levels of government funding—satisfies the above mentioned, quite general assumptions.

3.3 Governments and GHG Emissions

An institution authorized by the climate agreement auctions emission permits for ETS emissions to firms in the private sector in each country, ensuring that $\sum_i \varepsilon_i^* = \bar{\epsilon}$. The auction results in the ETS permit price $\rho^{eq} = \rho^{eq}(\bar{\epsilon})$. The proceedings from the auction $\rho^{eq}(\bar{\epsilon})\bar{\epsilon}$ is redistributed to the countries in a predetermined manner such that each country receives ϱ_i, an exogenously determined share of the total proceedings from the auction.

For the non-ETS emissions, the climate agreement allocates emission quotas $\bar{e}_i$ to countries such that $\sum_i \bar{e}_i = \bar{E}$. In order to highlight the effect of fiscal externalities in permit markets, we assume that governments regulate their respective non-traded GHG emissions e_i by direct regulation and also control the residual $(\bar{e}_i - e_i)$.[11] Country i's net revenue from trading emission permits in the non-ETS sector, which may be positive or negative, is then given by $p^{eq}(\bar{e}_i - e_i)$, where p^{eq} is the equilibrium permit price on the non-ETS permit market.

[9] We assume that all permits are auctioned, which is not strictly the case in the ETS. Still, we do not model free allocations of permits to firms here as this does not influence our main results.

[10] The Inada conditions imply: $w_y^i(y_i) > 0$; $w_{yy}^i(y_i) < 0$; $\lim_{y\longrightarrow 0} w_y^i(y_i) = \infty$; $\lim_{y\longrightarrow\infty} w_y^i(y_i) = 0$; $h_G^i(G_i) > 0$; $h_{GG}^i(G_i) < 0$; $\lim_{G\longrightarrow 0} h_G^i(G_i) = \infty$; $\lim_{G\longrightarrow\infty} h_G^i(G_i) = 0$.

[11] We relax this assumption in Sect. 7.1.

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In addition to regulating the levels of emissions in their respective countries, the countries' governments are responsible for the provision of public goods. We assume that the governments freely decide on a tax rate t_i on private income, and a level of public goods provision G^i, so as to maximize social welfare. The tax rate in any country i is, however, potentially constrained by the country's fiscal capacity, $\tau^i \in (0, 1)$, implying

$$t_i \leq \tau^i. \tag{6}$$

The fiscal capacity parameter τ can be interpreted as in Besley and Persson (2010): "In concrete terms, τ represents fiscal infrastructure such as a set of competent tax auditors, or the institutions necessary to tax income at the source or to impose a value-added tax".[12] For some countries, the fiscal capacity constraint may (occasionally) be binding, while for others it may not. The governments' budget constraints can then be stated as

$$G^i\left(t_i, e_i\right) \leq t_i \pi^i\left(e_i\right) + \varrho_i + p^{eq}\left(\bar{e}_i - e_i\right), \tag{7}$$

where the terms to the right of the "$\leq$" sign are private sector taxes, proceedings from the ETS permit auction and income from non-ETS permit sales, respectively.

The governments maximize welfare with respect to the tax rate and the level of emissions in the non-ETS sector,

$$\max_{t_i, e_i} u^i\left(y^i\left(t_i, e_i\right), G^i\left(t_i, e_i\right)\right) = \max_{t_i, e_i}\left[w^i\left(y^i\left(t_i, e_i\right)\right) + h^i\left(G^i\left(t_i, e_i\right)\right)\right], \tag{8}$$

subject to the constraints given by inequalities (6) and (7).[13]

Notice that our assumptions about the properties of $w^i(\cdot)$ and $h^i(\cdot)$ imply that the budget constraint, but not necessarily the fiscal constraint, holds with equality.

4 Taxation, Public Goods Provision and Emissions

Our model includes the following sequence of decisions. All national governments simultaneously set their levels of non-ETS emissions and tax policies, taking as given the permit price on the non-ETS market and their own caps on the non-ETS emissions. The non-ETS sectors in each country abate emissions such that the desired levels of emissions are reached. The governments collect taxes, procure permit sales (acquisitions) such that the country caps are fulfilled, and provide public goods. Note that, since no strategic interaction is taking place, agents' decisions can be analyzed separately.

4.1 Optimal Policy When the Fiscal Constraint is Not Binding

To save notation, we drop the country indexation i until we consider the market equilibrium in Sect. 5, and we denote the first derivatives of $w(\cdot)$ and $h(\cdot)$ by w_y and h_G, respectively, noting that all of these are functions of all of the exogenous variables and the parameters of the model (i.e., of $\bar{e}$, τ, and $\bar{\pi}$).

[12] The parameter τ can also be given a simple Laffer-curve interpretation: in a micro-founded setup, any agent's effort is equal to 1 as long as $t_i \leq \tau^i$, and drops to 0 as soon as $t_i > \tau^i$. Of course, it would also be possible to endogenize τ^i by introducing a continuous Laffer-curve, but as far as we can see, this would not generate any new insight.

[13] The environmental damages to the country resulting from the aggregate emissions $\bar{\epsilon} + \bar{E}$ are not included in the welfare expression. Even though global damage reduces welfare, it does not influence the optimally chosen levels of taxation and emissions. This is so because global damage, $D(\bar{\epsilon} + \bar{E})$, is given by the treaty, and therefore also the damage accruing to country i.

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Given that each country is too small to take into account its own impact on the equilibrium prices, ρ^{eq} and p^{eq}, a given government's objective function can be restated as

$$\max_{t,e} \left[w\left((1-t)\left(\hat{\pi} - C(e)\right)\right) + h\left(t\left(\hat{\pi} - C(e)\right) + \varrho + p^{eq}\left(\bar{e} - e\right)\right)\right], \tag{9}$$

which is solved subject to Eq. (6), and where industrial income $\hat{\pi}$ takes into account the ETS equilibrium (as defined in Sect. 3.2). If the fiscal constraint is not binding, the two first-order conditions simplify, after rearranging, to:

$$h_G = w_y; \tag{10}$$

$$-C_e = p^{eq}. \tag{11}$$

Hence, when the fiscal constraint is not binding, the decisions on taxation and public spending on the one hand, and which emission level to implement on the other hand, are effectively separated. Fiscal policy, t and G, should then be set such that the marginal utility from private consumption, w_y, is equal to the marginal utility from consumption of the public good, h_G, and the level of emission should be such that the marginal abatement cost, $-C_e$ is equal to the equilibrium price of emission permits, p^{eq}.

Optimal policy can be derived from the first-order conditions. From Eq. (10) we have that the optimal level of public goods provision is given by

$$G^* = h_G^{-1}\left(w_y\right), \tag{12}$$

where $h_G^{-1}(\cdot)$ is the inverse of h_G, and the superscript * indicates that the allocation is consistent with the first-best fiscal policy vector of the welfare maximizing government. By Eq. (11), the optimal level of emission of the country is given by

$$e^* = C_e^{-1}\left(p^{eq}\right). \tag{13}$$

where $C_e^{-1}(\cdot)$ is the inverse of $-C_e$.

Finally, the welfare maximizing tax rate is found by inserting from Eqs. (12) and (13) into the government budget constraint in Eq. (7),

$$t^* = \frac{G^* - \varrho - p^{eq}\left[\bar{e} - e^*\right]}{\hat{\pi} - C\left(e^*\right)}. \tag{14}$$

The expression in Eq. (14) implies that the optimal tax rate in a fiscally unconstrained country, t^*, can be negative if the share of the proceedings from the ETS auction, ϱ, and/or the amount of non-ETS quotas allocated to the country, $\bar{e}$, is sufficiently high. However, we consider this most unlikely as for all EU ETS countries we certainly have $G^* \gg \varrho + p^{eq}\left[\bar{e} - e^*\right]$.

4.2 Optimal Policy in Fiscally Constrained Countries

In the event that the fiscal constraint, given by Eq. (6), is binding, the government optimally sets $t^c = \tau$, and maximizes its objective function, Eq. (9), with respect to its non-ETS emissions, e. Notice that a fiscally constrained government ideally would like to set t even higher, but that the fiscal capacity of the country renders such a policy infeasible. The associated first-order condition of a fiscally constrained country is then given by

$$\left[p^{eq} - \tau\left(-C_e\right)\right] h_G = (1-\tau)\left(-C_e\right) w_y. \tag{15}$$

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On the left-hand side of (15) we have the marginal effect of more abatement on the utility from public spending. As long as p^{eq} is higher than τ $(-C_e)$, the government can increase its public spending by demanding more abatement from the private sector in exchange with more permit sales, which has a value of h_G. On the right-hand side of (15) we have the marginal effect of more abatement on the utility from private income.

Reorganizing Eq. (15), the first-order condition for the fiscally constrained country can be stated as

$$-C_e \frac{\tau h_G + (1-\tau)\, w_y}{h_G} = p^{eq}. \tag{16}$$

Note that the government no longer equates marginal abatement cost, $-C_e$, with the permit price, p^{eq}. In Eq. (16), the left-hand side represents the marginal *social* welfare cost of abatement, including how abatement affects the provision of public goods in the country. Hence, in addition to taking into account the production cost of abatement, captured by the $C(\cdot)$-function, the government also considers how emission trading affects welfare via the public funds and the supply of public goods. The term $\frac{\tau h_G + (1-\tau) w_y}{h_G}$ is, in effect, the factor by which the government discounts the marginal abatement costs due to fiscal concerns, when comparing these costs to the trading value of emissions. Note that the discounting of abatement costs is higher (i.e., the discount factor is lower), the more socially valuable are the public funds (i.e., the larger is h_G) and the lower is the fiscal capacity of the government (i.e., the smaller is τ, noting that $h_G > w_y$ in a fiscally constrained country). The intuition is that a fiscally constrained government is more concerned about the funding of public goods relative to cost-efficient abatement the more fiscally constrained it is. Interpreting Eq. (16), and comparing with the cost-efficient allocation in Eq. (11), we obtain the following result for the optimal level of emissions, e^c, in a fiscally constrained country:

Proposition 1 *If a country goes from being fiscally unconstrained to being fiscally constrained, its level of emissions will decrease, that is,* $e^c < e^*$.

Proof Comparing Eqs. (11) and (16), notice that $\frac{\tau h_G + (1-\tau) w_y}{h_G} < 1$ since, for any fiscally constrained country, $\tau \in (0, 1)$ *and* $h_G > w_y$. This implies that $-C_e > p^{eq}$, and hence that $e^c < e^*$. □

The total abatement cost function $C^G(\bar{E})$ is defined by (1). We know from textbook environmental economics that ε^* and e^* from (3) and (11) are solutions to (1) for the total cap $\bar{\epsilon} + \bar{E}$. It then follows from Proposition 1, since $e^c \neq e^*$, that total abatement costs will not be minimized when one or more countries are fiscally constrained. Note also that marginal abatement costs will generally vary across countries.[14]

One may question whether our results so far depend on the government directly regulating the emissions from the non-ETS sectors. By exposing these sectors to a national emission tax, the government could increase its revenues. To investigate the robustness of our results further, Sect. 7.1 we allow the government to obtain additional income from a national emission tax. We find that the permit market equilibrium with fiscally constrained countries remains invariant to this extension.

In Eq. (16), p^{eq} and e enter h_G through G, and e enters w_y through C. Thus, without further assumptions about the shape of $w(\cdot)$, $h(\cdot)$, and $C(\cdot)$ we cannot solve for an explicit

[14] Abating GHG can also result in lower levels of local pollution, such as sulphur. It could then be efficient not to equalize marginal abatement costs between countries. However, in order to focus on the fiscal incentive of permit trade, we abstract from the case of local pollution here.

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expression for the level of emission by the constrained country, $e^c(p^{eq})$. However, we can still evaluate the comparative statics on e^c with respect to the variables p^{eq}, $\bar{e}$, and τ, noting that p^{eq} is considered exogenous to the single country.

4.3 Comparative Statics

From Eqs. (13) and (16), and taking into account that $w(\cdot)$, $h(\cdot)$, and $C(\cdot)$ are implicit functions of all variables and parameters that are exogenous to the single country, it is clear that both e^* and e^c generally depend on $\bar{e}$ and p^{eq}. The comparative statics of e^* and e^c can be found by implicit derivation of Eqs. (13) and (16).

If fiscal capacity is not binding, implicit derivation of Eq. (13) with respect to e^* and the three parameters p^{eq}, τ, and $\bar{e}$ gives:

$$\frac{de^*}{dp^{eq}} = -\frac{1}{C_{ee}} < 0; \tag{17}$$

$$\frac{de^*}{d\bar{e}} = 0; \tag{18}$$

$$\frac{de^*}{d\tau} = 0. \tag{19}$$

Hence, a fiscally unconstrained country's level of non ETS emissions depends exclusively on the equilibrium price of emission permits, and not on its quota allocation or level of fiscal capacity. An increase in the permit price induces the government to decrease the level of emission since the increased price of permits makes selling emission permits more valuable than producing at the margin. The results in Eqs. (17)–(19) are standard results in the literature on emissions trading.

If a country is fiscally constrained, however, both τ and $\bar{e}$ may matter for the government's optimal level of non-ETS emission. We distinguish between countries that are net sellers of permits, that is, $\bar{e} - e^c > 0$, and countries that are net buyers, that is, $\bar{e} - e^c < 0$. The comparative statics on the level of emission, e^c, can be found by implicit derivation of the first-order condition in Eq. (15), and we summarize the results for a fiscally constrained country in the following propositions:

Proposition 2 *For a fiscally constrained country which is a net buyer of non-ETS emission permits we have* $\frac{de^c}{dp^{eq}} < 0$*, while for a fiscally constrained country which is a net seller of non-ETS emission permits we have* $\frac{de^c}{dp^{eq}} \gtreqless 0$.

Proof First, implicit derivation of Eq. (15) with respect to e^c and p^{eq} gives

$$\frac{de^c}{dp^{eq}} = \left[-\left(h_G - w_y\right) - h_{GG}\left[p^{eq} - \tau\left(-C_e\right)\right]\left(\bar{e} - e^c\right)\right]/D_s, \tag{20}$$

where

$$D_s = \left[w_y + \left(h_G - w_y\right)\tau\right]\left(-C_{ee}\right) + h_{GG}\left[\tau\left(-C_e\right) - p^{eq}\right]^2 + w_{yy}\left[\left(1-\tau\right)\left(-C_e\right)\right]^2.$$

We have $D_s < 0$, $-\left(h_G - w_y\right) < 0$ and $-h_{GG}\left[p^{eq} - \tau\left(-C_e\right)\right] > 0$ [see Eq. (16)]. Hence, $\frac{de^c}{dp^{eq}} < 0$ if $\bar{e} - e^c < 0$, and ambiguous if $\bar{e} - e^c > 0$. □

In the *net seller* case, there are two effects pulling in different directions: On the one hand, a higher permit price makes it more valuable on the margin to do abatement. Thus, the government substitutes income from taxing production with income from permit sales. On

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the other hand, the income from permit sales increases with the increase in the permit price, which makes it less necessary to do extra abatement to finance public goods. It it easy to see that the income effect might dominate the substitution effect, for instance if the difference $\bar{e} - e^c$ is large, and we then have the counter-intuitive result that a higher permit price leads to less supply of emission permits from the constrained country in question, $\frac{de^c}{dp^{eq}} > 0$.

In case a fiscally constrained country receives a higher quota, the effect on non-ETS emissions is unambiguous:

Proposition 3 *For a fiscally constrained country we have* $\frac{de^c}{d\bar{e}} > 0$ *independent of whether the country is a net buyer or a net seller of non-ETS emission permits.*

Proof Differentiation of Eq. (15) with respect to $\bar{e}$ gives

$$\frac{de^c}{d\bar{e}} = -h_{GG}\left[p^{eq} - \tau\left(-C_e\right)\right] p^{eq}/D_s > 0. \tag{21}$$

□

In this case there is only an income effect: For a given level of emissions, receiving a higher quota reduces the money spent on permit acquisitions or increases the income from permit sales. Hence, the country finds it less necessary to do abatement to finance public goods. Note also that increasing the share of the proceedings from the ETS auction, ϱ, will reduce the need to do abatement to finance public goods.

Finally, we take a look at the effect of an increase in fiscal capacity:

Proposition 4 *For a fiscally constrained country we have* $\frac{de^c}{d\tau} > 0$ *independent of whether the country is a net buyer or a net seller of non-ETS emission permits.*

Proof Differentiating Eq. (15) with respect to e^c and τ gives

$$\frac{de^c}{d\tau} = \frac{1}{D_s}\left[\left(h_G - w_y\right)\left(-C_e\right) - \left(1-\tau\right)\left(-C_e\right) w_{yy}\hat{\pi} - \left[p^{eq} - \tau\left(-C_e\right)\right] h_{GG}\hat{\pi}\right] > 0. \tag{22}$$

□

Again we have a substitution effect and an income effect, but this time pulling in the same direction. First, a higher income tax makes it more costly on the margin to do abatement since the loss in fiscal income becomes higher when real output decreases. Thus, the government substitutes income from permit sales with income from taxing the real economy by increasing emissions. Second, for a given level of abatement fiscal income increases, which makes it less necessary to do extra abatement to finance public goods.

For the remainder of the paper we assume:

Assumption A1 $\left(h_G^k - w_y^k\right) > -h_{GG}^k\left[p^{eq} - \tau_k\left(-C_e^k\right)\right]\left(\bar{e}_k - e_k^c\right), \forall k.$

Thus, we assume away the possibility that fiscally constrained countries will respond to a decreasing permit price by abating more emissions (Proposition 2).[15]

[15] Notice that, in the symmetric case where all countries are initially identical, we have $\bar{e}_i - e_i^* = 0$. Then, if one or more countries k become fiscally constrained, for example due to a sudden jump in h_G^k, Assumption A1 will hold. More generally, Assumption A1 holds as long as the curvature of $h^j(\cdot)$ is relatively moderate, that is, if the value $\left|h_{GG}^j\right|$ is not too high.

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5 Non-ETS Permit Market Equilibrium

The condition for non-ETS market clearing is given by:

$$\bar{E} = \sum\nolimits_n e_i. \tag{23}$$

The market clearing condition in Eq. (23) implicitly pins down the equilibrium price p^{eq}. Denote fiscally unconstrained countries by j, and constrained countries by k. The equilibrium price is then given implicitly from the following equation:

$$\sum_j e_j^* \left(p^{eq}\right) + \sum_k e_k^c \left(p^{eq}\right) = \bar{E} \tag{24}$$

The proposition below then follows:

Proposition 5 *The non-ETS equilibrium price in the case in which all countries are fiscally unconstrained must be higher than the equilibrium price in the case in which one or more countries are fiscally constrained.*

When a country goes from being fiscally unconstrained to being constrained, its equilibrium level of emissions decreases (Proposition 1). Thus, we will have $\sum_j e_j^* \left(p^{eq}\right) + \sum_k e_k^c \left(p^{eq}\right) < \bar{E}$. To restore equilibrium in the permit market, the price has to fall such that both unconstrained and constrained countries increase their emissions. Note that all constrained countries will react in this way as long as the substitution effect dominates the income effect from a decline in the equilibrium price p^{eq} (Assumption A1).

A change in the quota allocation could also have implications for the market equilibrium, as given in Eq. (24). If a constrained country receives a higher emission quota for the non-ETS emissions, the country will increase its emissions from the non-ETS sectors (Proposition 3). Thus, we will have $\sum_j e_j^* \left(p^{eq}\right) + \sum_k e_k^c \left(p^{eq}\right) > \bar{E}$, and by Assumption A1 the quota price has to increase. We then have the following corollary:

Corollary *In the case in which one or more countries are fiscally constrained, a change in the quota allocation has real effects, that is, it changes the equilibrium permit price, and hence also the levels of abatement in both fiscally constrained and fiscally unconstrained countries.*

This result has some resemblance with Hahn's (1984) result, that when some country may obtain market power in a global quota market, the market power problem can be removed by changing the quota allocation. In our case it might be possible to allocate the quotas such that no country is constrained in the permit market equilibrium. However, achieving such an allocation may involve politically infeasible allocations. Also note that a change in the fiscal capacity of any of the fiscally constrained countries will have real effects.

If one or more countries k become fiscally constrained, for example due to a sudden jump in h_G^k, how does that affect the welfare of the other countries? Countries are only affected through the permit price. Subject to constraints (6) and (7), using the envelope theorem on Eq. (8) gives

$$\frac{\partial u^i}{\partial p_i^{eq}} = h_G^i \left(\bar{e}_i - e_i\right),$$

where $h_G^i = w_y^i$.

The permit price is lower in a fiscally constrained market equilibrium, and we therefore have the following proposition:

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Proposition 6 *If one or more countries become fiscally constrained, unaffected countries will gain if they are net buyers of emission permits before and after the change in the permit price, and lose if they are net sellers of emission permits before and after the change in the permit price.*

For countries that change from being net sellers to becoming net buyers, we cannot say in what direction their welfare changes.

There are three factors that determine whether a country becomes a net seller or a net buyer of non-ETS permits: its initial allocation of permits, its abatement costs, and the extent to which it is fiscally constrained. Usually, countries that receive a high initial allocation of permits and have low abatement costs will be net sellers. However, fiscal constrainedness will serve as an extra incentive to become a seller.

6 A Carbon Tax for Non-ETS Sectors

On the one hand, one could argue that the non-ETS permit market outcome we have studied so far is efficient. The "true" (social) marginal abatement cost in fiscally constrained countries does not only include losses in production, but also the benefit of being able to increase the supply of public goods. Thus, it is not possible to increase welfare by interfering with the amount of permit sales, for instance, by restricting the amount of permits a country is allowed to sell. On the other hand, since total abatement costs, as defined in (1), is not minimized, one is left to wonder whether it is possible to improve on the outcome by changing the permit market institution. One option for change is to replace the permit market by a common carbon tax for the non-ETS sectors.

With concave utility from both private and public goods, all redistribution of income from high income countries to low income countries will improve global welfare. In order to isolate the effect on global welfare of the allocation of abatement effort, we assume w_g and h_G constant. In particular, we assume that the marginal utility from income is equal to unity, $w_y^i = 1 \forall i$, and that the marginal utility of public goods is given by $h_G^i = 1 + \alpha_i$, where $\alpha_i \geq 0 \forall i$. [16] Note that fiscally unconstrained countries, by definition, have $w_y^i = h_G^i$, and hence $\alpha_i = 0$. Welfare of the individual countries can then be written

$$u^i = \begin{cases} \hat{\pi}^i - C^i(e_i^C) + p^{eq}(\bar{e}_i - e_i^C) & \text{if } \alpha_i = 0 \\ \hat{\pi}^i - C^i(e_i^C) + p^{eq}(\bar{e}_i - e_i^C) & \\ \quad +\alpha_i \left[\tau^i(\hat{\pi}^i - C^i(e_i^C)) + p^{eq}(\bar{e}_i - e_i^C)\right] & \text{if } \alpha_i > 0 \end{cases},$$

where e_i^C denotes the emission levels in the permit market equilibrium in which one or more countries are fiscally constrained.[17]

[16] As we focus on the cases where public goods are either optimally provided ($\alpha_i = 0$) or underprovided due to fiscal constraints ($\alpha_i > 0$), we disregard the cases where they may be overprovided ($\alpha_i < 0$). While discarding overprovision may seem unrealistic, overprovision would be a result of political inefficiencies rather than fiscal constraints which could affect emission trading in a number of additional ways, depending on the source and nature of the inefficiency. Analyzing additional political inefficiencies are, however, beyond the scope of the current paper.

[17] Note that our notation no longer differ between the optimal emissions levels of fiscally constrained countries (e_i^c) and fiscally unconstrained countries (e_i^*), but simply denotes the individual country's emission level in the permit market equilibrium as e_i^C. Note also, as defined in Sect. 3.2, that industrial income $\hat{\pi}$ takes into account the ETS equilibrium.

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It is now possible to sum over the individual countries' welfare. Using that $\sum_i p^{eq}(\bar{e}_i - e_i^C) = 0$, we obtain

$$U^C = \sum_i \left[\hat{\pi}^i - C^i(e_i^C)\right] + \sum_k \alpha_k \left[\tau^k(\hat{\pi}^k - C^k(e_k^C)) + p^{eq}(\bar{e}_k - e_k^C)\right], \qquad (25)$$

where U^C denotes welfare in the non-ETS cap-and-trade case and k denotes the fiscally constrained countries.

We now introduce a common carbon tax which is levied on all non-ETS emissions, and a predetermined redistribution scheme that allocates the revenue from the tax to the countries (as for the proceedings from the ETS auction). The tax is set such that total non-ETS emissions sums to $\bar{E}$. Denote the tax by θ. Since all emitters face this price, we will obtain the cost minimizing levels of emissions e_i^θ. The different participating countries' levels of welfare are then given by

$$u^i = \begin{cases} \hat{\pi}^i - C^i(e_i^\theta) - \theta e_i^\theta + \varphi_i \theta \bar{E} & \text{if } \alpha_i = 0 \\ (1-\tau^i)(\hat{\pi}^i - C^i(e_i^*) - \theta e_i^\theta) \\ \quad +(1+\alpha_i)\left[\tau^i(\hat{\pi}^i - C^i(e_i^\theta) - \theta e_i^\theta) + \varphi_i \theta \bar{E}\right] & \text{if } \alpha_i > 0 \end{cases},$$

where φ_i is the predetermined level of redistribution of the income from the carbon tax to the individual countries. Adding the individual welfare levels, and using that $\sum_i \varphi_i \theta \bar{E} - \theta e_i^\theta = 0$, we obtain

$$U^\theta = \sum_i \left[\hat{\pi}^i - C^i(e_i^\theta)\right] + \sum_k \alpha_k \left[\tau^k(\hat{\pi}^k - C^k(e_k^\theta) - \theta e_k^\theta) + \varphi_k \theta \bar{E}\right], \qquad (26)$$

where U^θ denotes welfare in the common non-ETS tax case and k denotes the fiscally constrained countries.

The difference in welfare between the common tax case and the cap-and-trade case, that is, Eq. (26) subtracted Eq. (25) is, after some rearranging, given by

$$\begin{aligned} U^\theta - U^C = & \sum_i \left[C^i(e_i^C) - C^i(e_i^\theta)\right] \\ & + \sum_k \alpha_k \tau^k \left[C^k(e_k^C) + \theta e_k^C - C^k(e_k^\theta) - \theta e_k^\theta\right] \\ & + \sum_k \alpha_k \left[\theta(\varphi_k \bar{E} - \tau^k e_k^C) - p^{eq}(\bar{e}_k - e_k^C)\right]. \end{aligned} \qquad (27)$$

The first term in Eq. (27) is clearly positive as long as $e_i^C \neq e_i^\theta$ for some i, since, given the cap $\bar{E}$, abatement costs are minimized when $e_i = e_i^\theta \forall i$. The second term is also positive. Given the common carbon tax θ, e_k^θ is the level of emissions which minimizes the sum of permit acquisitions and abatement costs for each country (also the fiscally constrained countries). The terms taken together are the benefit of reducing total abatement costs as the tax eliminates the fiscal externality.

Finally, the third term can be made positive for the appropriate choice of φ_k. That is, as long as φ_k is set such that $\sum_k \varphi_k \bar{E} \geq \sum_k \bar{e}_k$, the term must be positive since $\theta > p^{eq}$ and $\sum_k \tau_k e_k^C < \sum_k e_k^C$. The third term reflects that providing more public goods in fiscally constrained countries may be carried out more effectively by redistributing the revenue from a common carbon tax than by allowing the same countries to cover their fiscal gap through permit sales.

Hence, we have for the non-ETS:

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Proposition 7 *Welfare can be increased if a common carbon tax is introduced instead of permit trade, and the income from the tax is redistributed to the countries in a predetermined way.*

We conjecture that the assumption of constant marginal utilities of income and public goods does not affect this result. Given the large budgets for public spending in the EU compared to the income from a non-ETS carbon tax, the shift from a non-ETS permit market to a common carbon tax will likely only change the provision of public goods marginally.

Note also that not all redistribution schemes will increase welfare. The redistribution scheme must take into account that countries have different marginal utilities from public goods, that is, different levels of α. The EU already has a redistribution scheme in place for the emissions in the ETS where the commission auctions permits to firms, and the proceeds are paid back to the member states by a predetermined scheme.

7 Extensions

7.1 Income from National Carbon Tax

We have assumed that governments implement their national emission targets by direct regulation of the private sector, and that governments do not obtain any fiscal income from national regulation of GHG emissions. That governments do not levy national carbon taxes and can only obtain income from national emission reductions by selling emission rights to other countries is obviously an extreme case. In reality, many EU countries use national emission taxes. Here, we consider the opposite extreme case by assuming that governments are fully capable of levying national emission taxes even if they are otherwise fiscally constrained. As above, we skip the index i since we will only analyze the single EU country.

In this version of the model the government sets a national emission tax κ instead of e, and its budget constraint is given by

$$G(t, e) \leq t\left[\bar{\pi} - C(e)\right] + (1-t)\kappa e(\kappa) + p^{eq}\left(\bar{e} - e(\kappa)\right), \tag{28}$$

where $e(\kappa)$ is the national emissions as a function of the national tax. We assume $e'(\kappa) < 0$. The welfare expression is given by

$$\begin{aligned} u = {} & w\left((1-t)\left[\bar{\pi} - C(e) - \kappa e(\kappa)\right]\right) \\ & + h\left(t\left[\bar{\pi} - C(e)\right] + (1-t)\kappa e(\kappa) + p^{eq}\left(\bar{e} - e(\kappa)\right)\right). \end{aligned}$$

In this version of the model the government maximizes u with respect to κ and t given $t \leq \tau$. The first-order condition with respect to the national emission tax writes

$$\begin{aligned} \frac{\partial u}{\partial \kappa} & = w_y(1-t)\left[-C_e e'(\kappa) - \kappa e'(\kappa) - e(\kappa)\right] \\ & \quad + h_G(-tC_e e'(\kappa) + (1-t)\kappa e'(\kappa) + (1-t)e(\kappa) - p^{eq} e'(\kappa)) \\ & = 0. \end{aligned}$$

The private sector sets $-C_e = \kappa$. The first-order condition can thus be simplified to

$$\frac{\partial u}{\partial \kappa} = (h_G - w_y)(1-t)e(\kappa) + h_G(\kappa - p^{eq})e'(\kappa) = 0. \tag{29}$$

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For the optimal tax t^* we have, as before,

$$\frac{\partial u}{\partial t} = (h_G - w_y)\,[\bar{\pi} - C\,(e) - \kappa e(\kappa)] = 0. \tag{30}$$

From (30) we see that a fiscally unconstrained government sets t such that $h_G = w_y$ and Eq. (29) can then only hold if $\kappa = p^{eq}$. Hence, the strictly defined cost-efficient outcome is obtained.

Alternatively, the government might be fiscally constrained, that is $t^* > \tau$. The government will then set $t = \tau$, and we have $h_G > w_y$ in equilibrium. In Eq. (29) we then note that $(h_G - w_y)(1 - t)e(\kappa) > 0$. In order for Eq. (29) to hold with equality, we must have $h_G(\kappa - p^{eq})e'(\kappa) < 0$. Since $e'(\kappa) < 0$, we must have $\kappa - p^{eq} > 0$, which implies excessive abatement in fiscally constrained countries. Thus, if the government can increase its public spending by taxing emissions at home and the government is fiscally constrained, the fiscal incentive still ruins the efficiency properties, strictly defined, of the non-ETS permit market.

7.2 Fiscal Capacity Dynamics

The fiscal capacities of countries are endogenous and will change over time. Notice, however, that while the model we analyze is static, extending it to a dynamic framework is straightforward. In such a framework, the fiscally constrained countries would optimally invest in expanding their fiscal capacities subject to their rational expectations of future outcomes. These expectations include the expected probability, and the associated social welfare loss, of being fiscally constrained in the future, and expectations about the nature of a future climate treaty.

We conjecture that, as long as governments are not too risk averse, the optimal investment path for fiscal capacity will never be so steep that it completely eliminates the chance of ever being fiscally constrained in the future. Hence, one can easily extend the model to a dynamic framework where countries will occasionally be fiscally constrained (according to some stochastic process), and all of our main results thus remain robust to endogenizing fiscal capacity.

Interestingly, an additional conjecture in this type of dynamic setting is that the incentives for fiscally constrained governments to invest in fiscal capacity will be weakened by the introduction of international cap and trade, the intuition being that cap and trade endows governments with a fiscal instrument to partially alleviate their fiscal constrainedness.[18] Hence, in addition to the observation that the results from the static model also carry over to a dynamic setting, there would be an additional effect arising from the weakened incentives of fiscally constrained governments to invest in future fiscal capacities. Notably, this latter effect will slow down the pace at which the most fiscally constrained countries gradually become less fiscally constrained over time, potentially lowering the development prospects of these countries.[19]

[18] Besley and Persson (2013) discuss this type of dynamic in the case of aid and natural resources. As (potentially large) caps to developing countries represent (potentially large) pure wealth transfers, their analysis straightforwardly extends to the case of a Kyoto-type cap and trade system.

[19] Specifically, economic development may be depressed if fiscal and other types of growth promoting state capacities (e.g., legal capacity) act as strategic complements, as in Besley and Persson (2011). Jensen (2011) presents evidence suggesting that resource windfalls retard state capacity development, including fiscal capacity.

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7.3 R&D and Dynamic Efficiency

Private investors spending resources on research and development (R&D) for developing better pollution abatement techniques will look to the value of a potential patent when deciding how much to invest (see, e.g., Laffont and Tirole 1996). Generally, the higher the price on emissions, the higher is the value of a patent, and only as long as the price on emissions is efficient can we expect the incentives for R&D on pollution abatement techniques to be sufficient to compete with the incentives for R&D on normal market goods. Proposition 5 suggests that the permit price is lower than the efficient price in the market equilibrium in which one or more countries are fiscally constrained. Thus, if the bulk of global R&D on GHG pollution abatement techniques happens in fiscally unconstrained countries based on the price on emissions in these countries, we conjecture that cap and trade could hamper dynamic efficiency. Higher permit prices will have a positive effect on innovation, which might be welfare improving in the longer run (see Cian and Tavoni 2012).

8 Discussion and Conclusion

A largely ignored side-effect of a cross-national emission trading system for pollution control is that it endows all participating governments with the opportunity to trade a valuable resource—the right to emit GHG—in a liquid market. A fiscally constrained government should optimally take advantage of this source of government funds to narrow its fiscal gap. Specifically, a fiscally constrained government should cut emissions until the marginal social (in terms of welfare), rather than industrial, cost of abatement equates the market price of emission permits. Consequently, if some (one or more) countries are fiscally constrained, the efficiency properties of a global (or regional) GHG permit market are hampered.

First, the market price of emission permits and the allocation of GHG abatement effort across countries will no longer be insulated from the initial allocation of emission caps across countries. Second, marginal abatement costs strictly defined will not be equalized across countries, and global GHG abatement costs, that is, the losses in production due to GHG mitigation, will not be minimized. Thus, in a second-best world where countries are frequently fiscally constrained, global welfare may be improved by exchanging the (non-ETS) cap-and-trade institution with a system-wide (non-ETS) carbon tax coupled with a predetermined redistribution scheme for the tax revenue. Of course, the standard prices-versus-quantities considerations under inadequate information and uncertainty (Weitzman 1974) remain and must be carefully considered in a real-world application, but we argue that adding fiscal constraints to the system strengthens the case for price regulation.

One fundamental assumption that we make is that governments are always fully capable of regulating national emissions, either directly or indirectly via a national carbon tax. However, note that this need not happen in a cost efficient way. One could imagine that a fiscally constrained government regulates emissions through brute force. The most straightforward way would simply be to force those polluting industries that contribute the least to social welfare to shut down. Such a country would likely not be abating its emissions efficiently, however, the fiscal incentive created by the permit market would still apply and probably amplify the loss from the inefficient regulation of emissions.

Our analysis may also be relevant for the Clean Development Mechanism (CDM). CDM has been compared with a cap-and-trade system in which some countries (e.g., the non-Annex 1 parties to the Kyoto Protocol) have their business as usual emissions as a sort of moving

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cap. According to our hypothesized mechanisms, a fiscally constrained country involved with the CDM mechanism would be interested in selling CDM permits to marginal costs above the international CDM price. We do not know to what extent this takes place, which makes it an interesting area of future research. It would be particularly interesting to look into the big dam projects that have been forwarded as CDM projects. Several of these projects have been criticized for not taking into account the social and environmental costs of dam building (see, e.g., Haya and Parekh 2011), suggesting that national governments have been willing to initiate projects at high marginal costs to obtain fiscal revenue by selling CDM permits at the international market.

While this paper focuses on a specific source of inefficiency in an international cap-and-trade system, there may also be other, and potentially even more severe, problems with cap and trade. One issue, that is already studied, is the extent to which countries will have market power in the permit market. If a permit selling country has market power, the country will limit its supply to increase the permit price. If this country at the same time is fiscally constrained, we may thus have two effects opposing each other. If on the other hand, a permit buying country has market power (and is not fiscally constrained), it will limit its demand to get a lower price which may exacerbate the inefficiencies resulting from other countries being fiscally constrained. Actually, in this case the mechanism has similarities to the supplementary principle which we analyze in Sect. 7.

Another issue is to what extent revenues from emission trading could have negative resource-curse effects, as have been claimed to be the case for natural resource income and aid. The fact that developing countries are likely to have comparably lower GHG abatement costs than developed countries implies that developing countries will be net sellers of emission permits. A recent study by the IISD (2009) estimates that revenues from permit sales to developing countries could reach US$300 billion already in 2020. Such a large transfer to developing countries has close resemblance with the discovery of a highly valuable renewable resource, or foreign aid. Given the evidence on the natural resource curse (see van der Ploeg (2011) for an overview of this literature), and aid (Djankov et al. 2008) this possibility must be taken seriously.

Natural resources and foreign aid share several common characteristics: they can be appropriated by corrupt politicians without having to resort to unpopular, and normally less profitable, measures like taxation; the money from aid and resource revenue often go directly into the hands of state leaders; the amount of revenues from aid and resource income is not always transparent to the public; they produce foreign currency earnings that, if not neutralized by monetary policy, will raise the real exchange rate, undermining the competitiveness of other sectors (known as the Dutch disease). All of these characteristics could also be linked to revenues from emission trading, and the self-interest of potentially corrupt political elites would add to the welfare motivated fiscal incentive. This is another avenue by which permit trade can hamper the efficiency properties of permit markets through fiscal incentives which should be a topic of future research.

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