Markets for Tradable Emission Permits with Fiscal Competition *

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Abstract

We model an international market for tradable emission permits in which firms trade their permits endowment, and a non-cooperative energy tax setting game amongst countries. Countries can auction a share of their permit endowment and issue the remainder for free to a representative firm. We show how equilibrium taxes depend on the proportion of permits which is auctioned, on the total amount of permits in the market, on the allocation of permits across countries and on the number of participating countries. We also show how the creation of the market in a previously unregulated world changes energy taxation. Finally, we highlight that, despite the permits market being perfectly competitive, it does not achieve emission abatement in a cost-efficient way.

Keywords: tradable permits, fiscal competition, EU-ETS, Kyoto protocol.

JEL Classification: Q48; Q52; H23; H73

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1 Introduction

 Tradable emission permits (TEPs) have become a major policy instrument with the entering into force of two large-scale international markets. On the one hand, a worldwide market is emerging for greenhouse gases under the Kyoto protocol.\(^1\) On the other hand, the European Union Emission Trading Scheme (EU-ETS) already organizes trading for permits on carbon dioxide emissions among industrial firms within the EU.\(^2\) Yet, while being involved in such markets, each country still remains responsible for its own fiscal policy, notably the one on energy fuels, the main source of carbon dioxide emissions. Thus, we may expect strategic behavior, since a country’s fiscal policy can indirectly affect the equilibrium TEP price and, consequently, the compliance cost of the firms hosted in that country. Intriguingly, this interplay between TEPs and national taxes has been largely disregarded in the literature. The purpose of this article is to show that international markets for TEPs, such as under the Kyoto protocol or the EU-ETS, may deeply reshape national energy taxation.

 There are two main reasons for countries to reshape their national energy taxes when joining an international TEP-market. Firstly, by accepting a supranational market-based instrument the countries get rid of emission regulation (since the global cap on emissions is set at the international level). However, they experience a cutback in their tax revenues since firms will have to reduce their energy consumption in order to decrease carbon emissions. Energy taxes representing a substantial source of revenue for most countries, reactions can be expected.\(^3\) Secondly, the firms involved in the market for TEPs bear an emission abatement cost and each country may be tempted to help the firms it hosts by reducing energy taxes.\(^4\)

 In this paper we show that the two previous arguments can be handled in a setting of fiscal competition. We consider firms which use fuels for production, and carbon emissions stem from fuels combustion. The emissions are regulated by a perfectly competitive international market for tradable permits. A proportion of the permits is freely given to the firms, while the remaining are auctioned by the governments. Energy taxes levied on fuel consumption are under the jurisdiction of national regulators, whose mandate combines firms’ costs, energy tax revenue, and TEP-auction revenue. We distinguish between regulators which attach more weight to the former (firm-oriented) and to the latter (revenue-oriented).

 We begin by looking at the TEP-market equilibrium. We show that national energy taxes depress the TEP price: countries have market power on the TEP-market,\(^1\) The Kyoto protocol came into force in February 2004 and the first commitment period will cover the years 2008 - 2012.

 \(^2\) The EU-ETS started in January 2005 and is operational since then.

 \(^3\) In 2005 the share of taxes in oil prices borne by the industry was 4.3% in Belgium, 4.8% in Japan, 4.9% in the United States, 13.6% in Germany, 20.3% in the UK and 46.2% in Italy (source: International Energy Agency, 2005). Energy tax revenue amounts to 5.2% of the total tax revenue on average, for the EU-15 (or 2.4% of GDP), ranging from 3.5% in the Netherlands and Belgium to 6.3% in the UK, 7.7% in Italy, and 8.4% in Portugal (source: Eurostat, 1997).

 \(^4\) As an example, a permit price of 30$ per ton of carbon dioxide roughly doubles the price of coal for the industry.
despite the competitive behavior of the firms. Such a market power is a source of externalities amongst countries. Firstly, the tax base of other countries varies because the cost of energy changes, the so-called fiscal externality. Secondly, the net payments from national to foreign firms also change because the TEP price varies, the so-called pecuniary externality. Both effects are known in the capital tax competition literature (see, e.g., Cremer and Pestieau, 2004, Wilson, 1999, for surveys).

In the analysis of the tax competition game, we pinpoint the three effects which drive the strategic interaction amongst countries and ultimately determine equilibrium taxes. We show that the higher the energy consumption, the higher the country’s incentive to tax (tax base effect); if national firms’ TEP demand is very responsive to the energy cost, taxation is discouraged (permit-leakage effect); finally, taxation is influenced by the net position of the country on the market for permits and by its market power (terms of trade effect).

We first consider the case of symmetric countries. This allows us to study how the TEP-market fundamentals affect equilibrium taxes, by looking, in turn, at the impact of the total amount of TEPs traded in the market, the number of participating countries and the very introduction of the TEP-market in a previously unregulated world. We then introduce asymmetry in countries’ TEP-endowment and show that larger permit endowments lead countries to tax less. Finally, we point to one important consequence of considering strategic tax setting: the international market for tradable permits does not lead to the minimization of total emission abatement costs. This contradicts the usual textbook wisdom and is due to the unequal Nash equilibrium tax rates which result from country heterogeneity (itself the result of firm asymmetry). Furthermore, we show that market outcome (and in particular the permit price) depends on whether the permits are grandfathered or auctioned.

Since the pioneering works of Dales (1968) and Montgomery (1972) the literature on tradable permits has followed many directions, some of them being related to our subject of concern.5

For many years now the literature has paid attention to the interaction between distortive taxation and optimal environmental policy. This has been popularized under the (sometimes fuzzy) concept of double dividend. Goulder (1995) provides an authoritative taxonomy of this concept. Much progress in our understanding of this interaction has occurred. In particular, Babiker et al. (2003) use a CGE model to show that the interplay between carbon policies and pre-existing taxes can differ markedly across countries, depending on the levels of prior distortive taxes in an economy. Notably, they argue that climate policies under consideration will likely not provide a weak double dividend in a number of European countries. This strand of literature, however, ignores the fact that country-level policies may react to the implementation of international climate policies.

Actually, the idea that country-level regulation may strategically interact with the

5The literature comparing the merits of policy instruments (prices versus quantities) is beyond the scope of our analysis. We do not compare instruments, we analyze the implications of adding a new instrument (tradable permits) on pre-existing ones (energy and carbon taxes).
market for TEPs has been little discussed in the literature\(^6\) or it has been addressed in indirect or implicit ways (see Cropper and Oates (1992), Coggins and Swinton (1996), Bui, 1998). There are some notable exceptions. The first, by Santore et al. (2001), examines the strategic behavior of state-level utility regulators in the context of the US federal trading system on sulfur oxide emissions. State-level regulators act independently of the federal authority by imposing pollution penalties on their own utilities. Like in our paper, Santore et al. show that emissions trading is not cost-efficient under fiscal competition. The second is an analysis of energy taxation and a TEP-market in a two-sector economy, by Eichner and Pethig (2007). The non-tradable sector’s emission target is attained with tax regulation, while the tradable sector participates in the international TEP-market and may also be subject to energy taxation (tax rates may differ across sectors). This paper also shows the inefficiency of energy taxation (in the tradable sector); in addition, they show that a permit-importing country has an incentive to tax, while a permit-exporting one faces a disincentive, a result which we also obtain in our setting. There is also the paper by Eichner and Pethig (2010) that on the interaction between international emissions trading and national green energy promotion policies.

None of these contributions provides, however, a characterization of Nash equilibrium taxes in terms of the underlying characteristics of the TEP-market, a task we undertake in the current analysis.

As regards climate policy issues, the fact that actual TEP markets diverge from the standard textbook has been addressed recently by Babiker et al. (2004). In particular, these authors emphasize the fact that the gains from trading can be outweighed by secondary costs associated with prior tax distortions and market imperfections, providing an illustration with the CGE model EPPA. In the same spirit, Copeland and Taylor (2005) use an international trade setting to show that the gains from trade can be ruined by terms of trade effects. This calls for further analyzing how markets for tradable emission permits may interplay with pre-existing policy instruments.

For that reason, the analysis carried out in our paper encompasses elements from both tax competition and TEP literatures in a comprehensive theoretical framework. Since countries tax energy and firms need permits to consume polluting energy, the TEP-market effectively creates a mobile tax base (the polluting permits). We model tax competition amongst countries which set energy taxes in a world where an international market for TEPs on carbon dioxide at the firm level (which parallels the Kyoto carbon market or the EU-ETS) is implemented. We replicate the basic property of such a setting, as Santore et al. (2001) and Eichner and Pethig (2007), i.e. the cost-inefficiency stemming from asymmetric national taxes, but we go deeper in the analysis of the Nash equilibrium in taxes, thus providing a more comprehensive insight of that market for policy support. In particular, as the latter paper, we highlight the importance of the net importing/exporting position of firms in a given country in the international TEP-market, which is reminiscent of the effect found in

\(^6\)For example, Oates’s book (2004) on environmental policy and fiscal federalism disregards this issue.
the capital tax competition literature by DePater and Myers (1994) and Peralta and
van Ypersele (2005).

The remainder of the paper proceeds as follows. The next section sets out the
model and preliminary results regarding the TEP-market and the main forces driving
strategic tax setting. The effects of the total number of TEPs and the number of
participating countries in equilibrium taxation are analyzed in Section 4, while section
5 is devoted to the comparison with autarky. We analyze the effect of firms’ TEP-
endowment and discuss how it can influence the efficiency of the TEP-market in
section 6. Section 7 concludes.

2 The model

We consider an economy composed of $N$ countries where a global pollutant is reg-
ulated by an international market for tradable emission permits (TEP). Hence, our
setting parallels the EU-ETS market. In addition, each country is responsible for its
own national energy tax.

2.1 The firms

Each country, indexed by $c$, hosts a representative firm.\footnote{The analysis would be unchanged if we supposed a continuum of price-taking firms in each
country; see Bréchet and Peralta (2007) for such an analysis.} We consider cost minimizing
firms which use a polluting input denoted by $e_c$ (typically, fossil fuels). The production
cost is $c(e_c)$, where $e_c$ is the energy consumed by the firm in country $c$, and $c'(e_c) < 0 <$
$c''(e_c)$. By normalization, we assume that one unit of energy consumption yields one
unit of pollution emission, which in turn corresponds to one polluting permit.\footnote{For example, carbon dioxide emissions are strictly proportional to the carbon content of the
fuels.} Firms take the price of energy, normalized to 1, as given. Given the production cost defined
above, it is immediate that, in the absence of regulation, the firm chooses a pollution
level $e^o$ such that $-c'(e^o) = 1$. In order to abate pollution below this unregulated level,
the firm bears an abatement cost $C(e_c) = c(e_c) - c(e^o)$, with $C'(e_c) < 0 < C''(e_c)$.

Pollution is regulated with an international market for tradable emission permits
(TEP) in which each firm is price-taker.\footnote{This is not a strong hypothesis, for the EU-ETS market covers more than 14,000 installations
over 27 countries in the European Union.} We denote the price of permits by $\rho$. In
addition, countries charge a unit energy tax $t_c$. Hence, the regulated cost of energy in
country $c$ is given by $p_c = 1 + t_c + \rho$.

The market for permits works as follows. The participating countries agree on a
global amount of permits $\bar{E}$ and on a way to split it among countries. The amount of
emission permits in country $c$ is denoted by $\bar{e}_c$. Each country then issues a proportion
$\alpha \in (0, 1)$ of these permits to the firms for free and auctions the remaining part, $(1-\alpha)$.\footnote{7\footnote{The analysis would be unchanged if we supposed a continuum of price-taking firms in each
country; see Bréchet and Peralta (2007) for such an analysis.}
Our parameter $\alpha$ thus measures the share of permits that are grandfathered. In each country the representative firm thus faces the following cost minimization problem

$$\min_{e_c} \ t_c e_c + \rho(e_c - \alpha \bar{e}_c) + C(e_c).$$

Hence, $e_c(p_c)$ is implicitly given by the first-order condition

$$-C'(e_c) = 1 + \rho + t_c = p_c,$$

and we have that

$$\frac{de_c}{dp_c} = e'_c = -\frac{1}{C''(e_c)} < 0,$$

hence, when the cost of energy increases, the firm pollutes less. We make two further assumptions on the demand for permits. Firstly, we assume that the demand is (weakly) convex, that is,

$$\frac{d^2 e_c}{dp^2_c} \geq 0$$

This assumption corresponds to the intuitive property that, as the regulated price of emissions increases, emissions decrease, but at a decreasing rate. Let us rewrite (2) as $-C''(e_c) \frac{de_c}{dp_c} - 1 = 0$, and differentiate it with respect to $p_c$. We get

$$-\frac{d^2 e_c}{dp^2_c} C''(e_c) - \left(\frac{d^2 e_c}{dp_c}\right)^2 C'''(e_c) = 0,$$

and since the first term is negative, the second must be positive, so the convexity of the demand amounts to assuming that $C'''(e_c) \leq 0$. Secondly, we assume that the demand for permits is not too convex, in the sense that the semi-elasticity of permit demand $\eta(p_c) = -\frac{e'_c(p_c)}{e_c(p_c)} > 0$ is increasing with $p_c$. Notice that when $p_c$ increases, $e_c$ decreases and $(-e'_c)$ decreases as well. Our assumption of increasing semi-elasticity amounts to say that the former (first-order) effect dominates the latter. It may also be seen as an upper bound on the convexity of firm’s permit demand.

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10 In the EU-ETS, free allocation ought to represent at least 95% of total allocation in the first phase (2005-2008), and at least 90% in the second phase (2008-2012). For an analysis of endogenous permits allocation, see e.g. Helm (2003) or Godal and Holtsmark (2010). For the EU-ETS, national allocations plans have been decided at the country level, but in close coordination with the EU Commission. See Ellerman et al. (2006) for an analysis of the whole procedure. See also the web site of the European Commission for up-to-date information on National Allocation Plans (http://ec.europa.eu/environment).

11 The assumptions on third order derivatives are common in the tax competition literature (Laussel and Le Breton, 1998, Peralta and van Ypersele, 2005).
2.2 The governments

Because the market for tradable permits sets an emission cap in the global economy, the environmental quality is now exogenous to each country. So national energy taxes become useless for regulating polluting emissions.\textsuperscript{12} Besides, the enter into force of the TEP market raises the production costs of the firms. Managing this cost increase constitutes a major concern for national governments when it comes to fiscal decisions regarding energy. Empirical evidence support how topical was this policy issue with the implementation of the EU-ETS. For example, such a concern was behind Sweden and Denmark’s July 2006 appeals to the European Commission for permission to cut their existing carbon taxes on the trading sector. After the implementation of the EU-ETS, those countries considered the co-existence of pre-existing carbon and energy taxes with emissions trading as double taxation which could jeopardize their competitiveness. Moreover, many countries are used to subsidizing energy production or consumption. For example, the OECD survey on \textit{Environmentally Harmful Subsidies} (OECD, 2005) reports calculations made by the U.S. Department of Energy’s Energy Information Administration (EIA). In 1999, the subsidies to the primary energy sector in the United States (based only on budgetary expenditures) amount to nearly USD 4 billion.

Consequently, we shall assume that the objective function of country \( c \) regulator is to maximize a weighted sum of energy tax revenue, permits auction revenue, net of firms production costs, the latter with a weight of \( \gamma > 0 \). Increasing the energy tax or the share of permits that are auctioned is revenue raising, but it is costly to the firms. So the regulator faces a trade-off. For the sake of exposition, let us characterize two regulator profiles. We shall refer to the case \( \gamma > 1 \) as the \textit{firm-oriented regulator} and to the case \( \gamma < 1 \) as the \textit{revenue-oriented regulator}.\textsuperscript{13} The objective of the regulator of country \( c \) is thus the following

\[
\max_{t_c} U_c = t_c e_c + (1 - \alpha) \rho \bar{e}_c - \gamma (t_c e_c + \rho (e_c - \alpha \bar{e}_c) + C(e_c)). \tag{3}
\]

Notice that countries are asymmetric, except if they have the same emission cap.\textsuperscript{14}

\textsuperscript{12}Actually, energy taxes can also be used for other sources of pollution rather than industrial \( \text{CO}_2 \) consumption (e.g., automobile usage), so they could still serve the purpose of regulating \textit{local} pollutants. We are thus making the simplifying assumption that the energy tax base is exclusively energy consumption by firms. We thank an anonymous referee for raising this point.

\textsuperscript{13}The assumption of a double mandate for the regulator is usual in papers dealing with pollution regulation. For instance, Requate and Unold (2003) assume that the regulator minimizes the sum of firms’ abatement costs and environmental damage.

\textsuperscript{14}Notice that in the alternative setting without the representative firm, countries are not perfectly symmetric to the extent that the firms with the same technology do not necessarily have the same TEP-endowment. All the results go through as long as all the countries have the same total TEP-endowment. Please refer to Bréchet and Peralta (2007) for details.
3 Preliminary results

In this section we introduce some preliminary results regarding the functioning of the TEP market, and the strategic effects of energy taxes in our setting.

3.1 Equilibrium in the market for tradable emission permits

Firms are price takers in the international TEP market. Each firm is endowed with \( \alpha \bar{e}_c \) emission permits, and the regulator auctions the amount \((1 - \alpha)\bar{e}_c\). Total permits supply in the TEP market is thus \( \sum_{c=1}^{N} \bar{e}_c = \bar{E} \). Individual firm demand \( e_c(p_c) \) is implicitly given by \(?\), hence the permits market clears when

\[ \sum_{c=1}^{N} e_c(p_c) = \sum_{c=1}^{N} \bar{e}_c = \bar{E} \]  

(4)

The following lemma states the existence and uniqueness of the equilibrium.

Lemma 1 There exists a unique permit price \( \rho(t, \bar{E}) \) that clears the market. Furthermore, assuming that \( \bar{E} < \sum_{c=1}^{N} e_c(1 + \bar{t}) \), the equilibrium permit price is strictly positive.

**Proof.** See Appendix. 

Notice that, to ensure a positive permit price in equilibrium, it suffices to impose a sufficient restrictive global emission cap. We shall see later in the paper why this common intuition may not be so straightforward when national taxes are endogenous with respect to the emission cap.

National energy taxes do have an impact on the market for TEP because they influence firms’ energy consumption, and thus pollution. Totally differentiating \(?\), one obtains

\[ \frac{d\rho(t, \bar{E})}{dt_c} = \rho_{t_c} = -\frac{e'_c(p_c)}{\sum_{j=1}^{N} e'_j(p_j)} < 0 \]  

(5)

The intuition works as follows. If a country increases its tax rate on the energy input, firms in that country reduce their energy consumption, thus asking for less permits. *Ceteris paribus*, the aggregate demand for permits decreases and the equilibrium price must decrease to clear the market. One should note that

\[ \frac{d e_c}{d t_c} = e'_c(1 + \rho_{t_c}) = e'_c \sum_{j \neq c} e'_j(p_j) \sum_{j=1}^{N} e'_j(p_j) < 0 \]

That is, if country \( c \) increases its energy tax, the equilibrium price of permits decreases, but still the cost of energy increases and the firms in that country pollute less. But as a consequence, the lower permit price leads to an increase in the emission level in all other countries in the economy, that is:

\[ \frac{d e_c}{d t_j} = e'_c \rho_{t_j} > 0, \ j \neq c \]  

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This means that every country potentially has some market power in the market for TEPs. It should be noticed that (1) can be rewritten as

\[ \rho_t = -\frac{\eta_t e_t}{\sum_{j=1}^{N} \eta_j e_j}, \]

from which it is clear that the impact of a given country’s energy tax rate on the TEP price is greater the greater is that country’s firm’s demand for permits, on the one hand, and, on the (semi-)elasticity of this demand, on the other hand. If the firms in that country react strongly to the increase in the energy cost, then it has a greater impact on the international market, and the country gets a stronger market power. In the following subsection these effects will be further analyzed, and we will show how they interact in equilibrium.

### 3.2 The strategic effects of energy taxation

We solve for a Nash equilibrium in energy taxes. The regulator in country \( c \) chooses \( t_c \) so as to maximize its payoff defined by (1). Notice that each regulator’s payoff depends on the tax choice of the other regulators via the permits price in equilibrium.

The first-order condition for the regulator’s problem (1) in country \( c \) writes as follows

\[
(1 - \gamma)e_c(p_c) + t_c \frac{d e_c(p_c)}{d t_c} - \rho_t (\gamma(e_c(p_c) - \alpha \bar{e}_c) - (1 - \alpha)\bar{e}_c) = 0 \quad (6)
\]

The above expression identifies the determinants of tax setting by each country. As usual in tax competition games with terms-of-trade effects, the conditions for the quasi-concavity of the payoff functions are cumbersome (see, e.g., Peralta and van Ypersele, 2005). Throughout the paper we are going to assume that (at least one) Nash equilibrium exists with tax rates defined by (1). There exists at least one class of cost functions (the quadratic one) which respects convexity of the abatement cost and increasing semi-elasticity of the TEP-demand where the unique Nash equilibrium is given by (15).

The first-order condition (1) allows us to identify three key equilibrium effects.

**The tax base effect:** the larger the energy consumption by the firm in country \( c \), the higher the country’s incentive to tax (as long as \( \gamma < 1 \)). This is weighted down by \( \gamma \), for an increase in the energy tax rate increases firms’ cost. The tax base effect becomes negative for \( \gamma > 1 \), i.e. when the regulator gives more weight to firm’s costs than to fiscal revenue.

\[ \text{In order to ensure concavity of the payoff functions in the quadratic case, one needs to assume further that } \gamma < \frac{2N}{N-1}. \text{ Details available from the authors, upon request.} \]
The permits leakage effect: provided that the tax base decreases with the tax rate, taxation is discouraged when the tax rate is positive, and encouraged otherwise. The magnitude of this effect depends on the country’s market power. To see this, notice that
\[
\frac{dc_e(p_c)}{dt_c} = (1 + \rho_t c) e'_c(p_c)
\]
Hence, a higher market power lowers the sensitivity of the tax base to the tax rate, for the TEP price absorbs a greater share of the tax increase. It is interesting to notice that the tax base and permit-leakage effect actually sum up to a Laffer curve, modified by \((1 - \gamma)\).

The terms of trade effect: this effect stems from the fact that the TEP price decreases with the country’s tax rate. When the country’s firm need to buy emission permits (i.e. when it pollutes more than its endowment), and when the share of grandfathering increases (i.e. a decrease in \(\alpha\)), then the regulator benefits from a lower \(\rho\) and has thus a higher incentive to tax. We shall refer to \((\gamma e_c(p_c) - \alpha \bar{e}_c) - (1 - \alpha) \bar{e}_c\) as the perceived importing position of country \(c\) in the market for permits. Notice that when \(\gamma = 1\) the perceived importing position is equal to the actual one, i.e., \(e_c(p_c) - \bar{e}_c\). Note also that when \(\alpha = 0\) the perceived importing position is equal to \(\gamma e_c(p_c) - \gamma \bar{e}_c\), which is smaller than the perceived importing position when \(\alpha = 1\), \(\gamma e_c(p_c) - \gamma \bar{e}_c\), when \(\gamma < 1\). Hence, grandfathering increases the perceived importing position of a country. It is thus a disincentive to tax, when \(\gamma < 1\).

Given (??), we have that the Nash equilibrium energy tax of country \(c\) is given implicitly by
\[
\hat{t}_c = \frac{(1 - \gamma) \hat{e}_c(p_c) - \hat{\rho}_t c \gamma (\hat{e}_c(\hat{p}_c) - \alpha \bar{e}_c) - (1 - \alpha) \bar{e}_c)}{-(1 + \hat{\rho}_t c) \hat{e}'_c(\hat{p}_c)}
\]
Where \(\hat{x}\) denotes the equilibrium value of the variable \(x\).

4 The emission cap, the number of countries, and energy taxes

We now study the impact of the fundamentals of the TEP-market on energy taxes. In order to do so, we focus on symmetric countries, i.e., we let \(\bar{e}_c = \bar{e} = \bar{E}/N\), \(\forall c\). We shall relax this assumption later. In this case it turns out that there exists a symmetric equilibrium where all countries set the same tax rate in equilibrium. Given that \(\hat{t}_c = \hat{t}, \forall t\), we also have that \(\hat{p}_c = \hat{p}, \forall c\), hence \(\hat{e}_c = \hat{e}, \forall t\). Equilibrium in the permit market then yields \(\hat{e} = \bar{E}/N = \bar{e}\). Given the symmetry of tax bases, we have that \(\hat{\rho}_t c = 1/N\). Let \(\eta\) be the semi-elasticity of TEP-demand evaluated at \(\hat{p}\) which respects \(e_c(\hat{p}) = \bar{E}/N, \forall c\). Straightforward simplification of (??) thus yields
\[
\hat{t}_c = \hat{t} = \frac{1}{\eta} (1 - \gamma) \frac{1 - \frac{1 - \alpha}{N}}{1 - \frac{1}{N}}
\]
Obviously, in the symmetric equilibrium the representative firm in each country consumes exactly the TEP-endowment of the country. However, the perceived importing position of each country is equal to \( \bar{e} ((\alpha - 1)(1 - \gamma)) \), which is equal to zero only when no permits are auctioned \((\alpha = 1)\). As soon as there is some auctioning, then the regulator perceives an exporting position when \( \gamma < 1 \), and an importing position otherwise. Indeed, when there is auctioning and the regulator is revenue-oriented, it gives a higher weight to permits endowment than to permits consumption, hence it behaves as if it were permits exporter. Conversely, a firm-oriented regulator \((\gamma > 1)\) gives a higher weight to permits consumption, so it behaves as if permits were imported in equilibrium.

We can now state our first result in the following proposition, which relates grandfathering and the regulator’s mandate to energy taxation.

**Proposition 1** *In the symmetric equilibrium,*

(i) ‘firm-oriented regulators’ subsidize energy, and the subsidy is increasing in the share of grandfathering,

(ii) ‘revenue-oriented regulators’ tax energy, and the tax raises with the share of grandfathering;

(iii) the permit price increases in the former case, and decreases in the latter case, with the share of grandfathering.

**Proof.** Straightforward derivation of (??), together with the fact that \( \rho \) is decreasing in tax rates. Also, it is obvious that when \( \gamma > 1 \), \( \hat{t} < 0 \). ■

As soon as some countries auction some permits, they have an incentive to decrease taxes. By doing so, they push the equilibrium price up, which in turn increases further the revenue from the auction. The relative importance of each of the regulator’s double mandate has a clear implication: when firm’s costs are more important than fiscal and auction revenue, then a country will subsidize energy consumption. The third item of proposition is of particular importance because it shows that the way permits are issued (grandfathered or auctioned) shapes market outcome and the equilibrium price. This is a new result in the literature where it is established that, under perfect competition and in a static setting, market outcome is independent of permits allocation.

We now turn to explore the effects of two main features related to the design of markets for TEPs: a change in the emission cap, and an enlargement of the market to new comers.

### 4.1 Changing the emission cap

A fundamental feature of the TEP-market is the fact that a global emission cap is assigned to the economy. The conventional wisdom about cap-and-trade markets is that a strengthening of the global emission cap unambiguously leads to an increase
in the permit price. As a consequence, the energy costs for firms should also increase. Does this still hold under strategic taxation? The following proposition addresses this question.

**Proposition 2** Strengthening the global emission cap always increases the energy cost, but not necessarily the permit price. In fact,

(i) if the regulators are ‘revenue-oriented’, then energy taxes decrease and the permit price increases,

(ii) if the regulators are ‘firm-oriented’, then energy subsidies decrease and the effect on permit price is ambiguous,

(iii) when grandfathering increases, energy taxes (or subsidies) and permit price display a smaller variation.

**Proof.** Given that each firm consumes $\bar{E}/N$, decreasing this value must be accompanied by an increase in the regulated cost of energy, by (??). The assumption that $\eta_c(p_c)$ is increasing in $p_c$ ensures that taxes decrease if they are positive, and increase otherwise. Since $\hat{p} = 1 + \hat{\rho} + \hat{t}$, when taxes increase, $\hat{p}$ can increase only if $\hat{\rho}$ increases. Straightforward derivation of (??) shows that when $\alpha$ decreases, equilibrium taxes depend less on the tax base.

When the emission cap becomes more stringent, firms in each country consume less permits in equilibrium, so its price must increase. Since the semi-elasticity of permit demand is increasing, its inverse is decreasing, hence tax rates decrease (or increase if they are negative i.e., subsidies decrease). When tax rates are positive, the permit price increases over and above what it would without strategic energy taxation: our setup entails an amplification of the effect of permit supply on its price.

### 4.2 Adding new countries

Let us now turn to an enlargement of the TEP-market. One or more countries may join the market. This is not a mere abstraction in our setting, since we are dealing with a market which is implemented amongst a set of countries and, logically countries outside this market may decide to join at some point. We neutralize the tax base effect by supposing that each new country receives exactly the TEP-endowment of the existing ones. Naturally, if the countries’ TEP-endowment decreases, one may apply a two-step reasoning whereby, firstly, new countries join the market and then the market becomes more stringent, as analyzed in Proposition 1.

**Proposition 3** Suppose the number of countries increases and each country’s permit endowment is kept constant. Then, the energy cost does not change, but the following holds:

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16For example, this may represent the impact of the EU enlargement on the ETS.
(i) if the regulator is ‘firm-oriented’, energy taxes decrease and the permit price increases,

(ii) if the regulator is ‘revenue-oriented’, energy subsidies decrease and the permit price decreases,

(iii) increasing grandfathering leads to a smaller variation in taxes and permit price and, with full auctioning, the number of countries does not impact energy taxes and permit price.

**Proof.** Straightforward derivation of (??) shows that \( \frac{dt}{dN} \leq 0 \) whenever \( \gamma \leq 1 \). Since firm’s energy consumption does not change, the regulated cost of energy must be kept constant, by (??). The fact that \( \hat{p} = 1 + \hat{\rho} + \hat{t} \) implies that \( \hat{\rho} \) varies in the opposite direction of \( \hat{t} \). Finally, letting \( \alpha = 0 \), (??) boils down to

\[
\hat{t} = \frac{1}{\eta}(1 - \gamma)
\]

which does not depend on \( N \).  

In order to understand this result, let us look at the two extreme cases of full grandfathering and no grandfathering. When all permits are given to the firms for free (\( \alpha = 1 \)), the perceived importing position is equal to zero, and the only effect of increasing \( N \) stems from the fact that the weight of each country on the international TEP market decreases, hence the permit-leakage effect becomes stronger because the TEP price absorbs a smaller proportion of tax increases. Indeed, in the symmetric equilibrium we have that

\[
\frac{de_c}{dp_c} = e'^c_c \left(1 - \frac{1}{N}\right).
\]

Hence, countries optimally respond by taxing (or subsidizing) less because their tax bases are more responsive to their tax choices.

Now let us look at the case where all permits are auctioned (\( \alpha = 0 \)). The permit-leakage effect is still the same. Tax revenue increases by 1, the direct impact of the tax, and auction revenue decreases by \(-1/N\), because \( \rho \) decreases. On the other hand, firm’s cost increases by 1, the direct impact of the tax, and decreases by \(-1/N\) because \( \rho \) decreases and so does TEP cost. Hence, the effect of the tax increase is everywhere proportional to \( 1 - (1/N) \) and the market power of the country no longer matters.

### 5 The effects of introducing a TEP market

Having understood the interplay between TEP-markets and energy taxation, we now turn to the analysis of the likely effects of introducing a TEP-market on a previously
unregulated economy. In the absence of a TEP-market, the optimal energy consumption by the firms is implicitly given by \(-C'_f(e_c) = 1 + t_c\). Countries maximize (??), with \(\rho = \bar{e}_c = 0\). Their first-order condition is then

\[
(1 - \gamma)e_c(t_c) + t_c \frac{de_c(t_c)}{dt_c} = 0. \tag{9}
\]

Using the fact that, in the absence of the TEP-market, \(de_c/dt_c = de_c/dp_c = e'_c\), the autarkic energy tax \(t^a_c\) is thus given by

\[
t^a_c = t^a = (1 - \gamma) \frac{1}{\eta^a}, \tag{10}
\]

where \(\eta^a\) denotes the semi-elasticity of permit demand when the price of energy is given by \((1 + t^a)\).

Let us now assume that a non-constraining TEP-market enters into force. By ‘non-constraining’ we mean that each country is endowed with a number of permits equal to its firm’s emissions in the absence of permits market. One could expect no changes in the economy, because the emission cap is non-binding. In fact, even this neutral form of emission market will change energy taxation, just because introducing the market creates mobility of the tax base (which is immobile under autarky). This result is provided in the following proposition.

**Proposition 4** Suppose a non-constraining TEP-market is introduced. Then, the energy cost remains constant but the following effects occur:

(i) ‘revenue-oriented’ regulators increase their energy tax, whereas ‘firm-oriented’ regulators increase their energy subsidy,

(ii) increasing the share of grandfathering makes the difference in energy taxation before and after the TEP-market stronger,

(iii) with full auctioning, energy taxes remain unchanged.

**Proof.** Using (??) and (??), and the fact that the market is non constraining, it is straightforward to obtain \(\hat{t}^a = (1 - \frac{1 - \alpha}{N})/(1 - \frac{1}{N}) \geq 1\), which is equal to 1 when \(\alpha = 0\).

Introducing a non-constraining TEP-market keeps the tax base at the same level. However, the responsiveness of the tax base to the tax rate declines, thanks to the partial absorption of the tax increase by the TEP-price. In other words, the cost of energy varies one-to-one with the tax rate in autarky, while it varies less under a TEP-market. This effect is responsible for a tax increase. The so-called run to the bottom result of the tax competition literature is sometimes interpreted as a decrease in the tax rate when borders are open, i.e., when the tax base becomes mobile. Proposition ?? shows that the exact opposite happens in our setting.

As auctioning permits is a disincentive to tax, the tax increase following the introduction of the market is greater when grandfathering is more important. In the
absence of grandfathering, we already know from Proposition 3 that the market power of the country does not matter for tax setting, hence the introduction of the market does not change energy taxes.

We can combine the results from Propositions 1 to 3 into Figure ??, which relaxes the assumption of the non-constraining market. This figure shows that, if the emission cap is below $E^*$, then the national energy taxes will decrease after the implementation of the market for tradable emission permits, whatever the number of countries. But when the market is binding, then taxes increase if the number of countries is not too large. Otherwise, they decrease.\footnote{\textsuperscript{17}Finding the critical number of countries $N^*$ could be the subject of a numerical analysis.}

6 \hspace{1em} Asymmetric permit endowments

In this last section we shall relax the assumption of symmetric permit endowments to grasp the effects of permits allocation on energy taxes in a general way. This will allows us to stress two more original results, the first related to country taxation, the second related to the efficiency of the TEP-market.

6.1 Permit endowments and national taxes

Let us pick up two countries from the economy, denoted by ‘A’ and ‘B’.

\textbf{Proposition 5} \textit{If the permit endowment of firms in country A is lower than in country B, and if taxes are strategic complements, then country A sets a higher tax than country B. Moreover, a TEP-importing country sets a higher energy tax than a TEP-exporting one.}

Figure 1: Energy taxes and the introduction of tradable permits

$E$

$E^*$

$N^*$

$N$

- taxes higher with market
- taxes lower with market
- taxes lower with market
Proof. See Appendix.

The intuition behind Proposition ?? rests on the terms of trade effect, which is an incentive to tax for a (perceived) importer, and a disincentive to tax for a (perceived) exporter. Since the country with the small endowment will (at a given tax rate) either import more, or export less, it has an incentive to set a higher tax rate. The comparison between importing and exporting countries depends on the sign of the terms of trade effect: it is positive for exporters, and negative for importers. For this result to hold, it is crucial that governments care for firms’ profits, i.e., γ must be bounded away from zero, otherwise the net importing position of firms in the international TEP-market is irrelevant for the government.

According to Proposition ??, countries ranking in terms of energy taxes is the inverse of the ranking in permit endowments. Following the same token as above, we can also answer a closely related question, namely, how does the equilibrium change if we switch the endowments of two different countries? The following corollary provides the answer.

Corollary 1 Suppose a reallocation of TEP endowments such that country A gets more permits and country B less, the total amount being kept unchanged. Then the energy tax decreases in country A and increases in country B, if taxes are strategic complements.

6.2 Cost-inefficiency of the market for tradable permits

In setting up a market for permits, the aim is to curb pollution in a cost-efficient way. This property of TEPs is widely put forward in the literature (since Montgomery, 1972) and generally used as an argument by its advocates (see e.g. IEA, 2006). This property, stated without strategic fiscal interactions, is questioned in our much more realistic setting.

The allocation of pollution emission is cost-efficient if, for a given quantity of aggregate pollution, the aggregate emission abatement cost is minimized. Formally, a cost-efficient pollution abatement is the solution of the following problem

\[
\min_{\{e_1, \ldots, e_N\}} \sum_{c=1}^{N} C(e_c) \quad \text{s.t.} \quad \sum_{c=1}^{N} e_c = \bar{E}.
\]

Hence, cost-efficiency is attained when \(C'(e_c) = \kappa\), \(\forall c\), where \(\kappa\) is a finite negative number. We show that, in the case of an international market with fiscal spillovers, this property does not hold anymore.\(^{18}\) Proposition ?? shows that energy taxes generically differ when countries have different permit endowments. Then follows Corollary 2.

\(^{18}\)Indeed, suppose that there are no energy taxes, i.e., \(t_c = 0\) in all countries. Then the choice of the energy input by the firms is such that \(-C'(e_c) = 1 + \rho\) and cost-efficiency is achieved.
Corollary 2. When countries set energy taxes non-cooperatively, equilibrium taxes are generically different. Hence, an international market for tradable emission permits is not cost-efficient.

This result shows that the efficiency gains of introducing a market are not realized if the power to tax energy inputs is left to the national initiative. This is a worrisome result, in that, as stressed in the introduction, empirical evidence confirms strong cross-country differences in energy taxation, which may be taken as evidence of asymmetries amongst firms locating in each country. This asymmetry will likely lead countries to set different taxes under the international TEP-market. Moreover, the relative importance of energy tax revenue in some countries makes it unlikely that all countries would be ready to give up their fiscal autonomy in this matter.

What does this result imply for the desirability of a TEP-market? There is one obvious way to overcome the inefficiency: adjust TEP endowment in such a way that countries set the same energy tax. In a setting of symmetric countries, this amounts to symmetric TEP endowments. In a more general setting where firms have different abatement cost curves, it suffices to endow each country with the exact TEP demand of its firm or firms, in a way that makes the perceived net importing position equal across countries. A related question is whether the TEP-market improves upon the autarkic situation. Naturally, if the environmental damage is taken into account, and there is over-pollution in autarky, then one may argue that it is better to achieve a reduction in pollution, even if not in a cost effective manner. This is not, however, the case in our setting. If one introduces a non-constraining market, as in Proposition 4, and if we allow the TEP-endowments to differ across countries, as in Proposition 5, then the abatement costs become asymmetric across countries. Indeed, the effect of introducing a market with asymmetric endowments is to introduce asymmetry in a previously symmetric world where marginal abatement costs were equated via tax-regulations. While this last result is arguably particular to our setting, the previous one that adjusting the allocation of permits across countries can be used to achieve efficiency (or, at least, decrease inefficiency) carries through to an asymmetric country setting.

It is important to notice that country asymmetry per se does not imply asymmetric taxation, rather it is the non-cooperative behavior that does so. If countries were to cooperate to minimize total abatement cost they would set equal tax rates.

7 Conclusion

With the background of the establishment of several environmental agreements at the international level, we analyze the interaction between an international market for tradable polluting permits and national energy taxes. The TEP-market introduces a mobile tax base between countries (the polluting permits), hence it creates room for fiscal competition.

Our analysis highlights the effects that drive tax choices: the tax base, the elasticity and the terms of trade effects. The interplay among these effects allows us to
characterize how equilibrium energy taxes depend on the fundamentals of the market: the total emission cap, the number of countries which join the market, and firms’ TEP-endowments. We also look at the impact of introducing the market on a previously autarkic world. Some of our results hinge on the nature of the strategic interaction amongst countries, i.e., whether taxes are strategic complements or substitutes. We show that this depends on the relative elasticities of the tax base and elasticity effects.

Increasing the restrictiveness of the market (i.e., decreasing the emission cap) leads to higher costs of energy, while taxes may either increase or decrease, depending on whether they are strategic substitutes or complements, respectively. On the other hand, if new countries join the market, then the cost of energy goes up while energy taxes decrease unambiguously. The introduction of the market has the opposite effect on energy taxation, i.e., countries increase their energy taxes because the TEP price partially absorbs tax increases, thus decreasing tax base sensitivity. Looking at firms’ TEP-endowment amounts to analyzing the impact of the terms of trade effect. We show that, under strategic complementarity, the country with the more endowed firms sets a lower energy tax and that importers tax energy more heavily than exporters. One interesting result of strategic taxation is that there is an amplifying effect on the TEP price, which in all cases varies more than what it would in the absence of taxes (when taxes are strategic complements).

Finally, considering strategic taxation leads us to question the usual argument in favor of an international TEP-market, namely, that it achieves emission reduction in a way that minimizes total abatement cost. This implies that the TEP-market only leads to cost effectiveness if it is accompanied by a tax harmonization policy. However, the political difficulties of implementing such a harmonization policy are at the very source of the creation of the international TEP-market.

One could envisage extending the model in several directions. Introducing a final good market is likely to discourage energy taxation (in that this causes a further distortion) in a symmetric way across countries, so that our results would remain qualitatively valid. Such an extension would call for a rewriting of the countries’ payoff function. The three effects highlighted in our analysis would still appear and would drive the results in a qualitatively similar manner. Finally, one could think of introducing a market for the energy input. If the market is perfectly competitive, our results go through unchanged. If instead it is an imperfectly competitive market, then the tax effects are likely to be mitigated. Indeed, say, a tax increase leads to a reduction in the demand for energy, hence decreasing its equilibrium price. This absorbs a part of the tax increase and leads to a mitigation of its effects, hence a lower incentive for the strategic use of taxes on behalf of the countries.

References


Appendix

Proof of Lemma 1
Recall the equilibrium condition on the market for TEPs (??). Since the left-hand side of (??) is strictly decreasing in \( \rho \), for each tax vector \( t = \{ t_1, \ldots, t_N \} \), and the global permits supply \( \bar{E} \) being given, there exists a unique permit price \( \rho(t, \bar{E}) \) satisfying (??). To see that \( \rho(t, \bar{E}) > 0 \), notice that

\[
\frac{d\rho(t, \bar{E})}{dt_c} = \rho_{tc} = -\frac{e_c'(p_c)}{\sum_{j=1}^{N} e_j'(p_j)} < 0
\]

hence the lowest equilibrium \( \rho(t, \bar{E}) \) arises when \( t_c = \bar{t}, \forall c \). This fact, together with the assumption that \( \sum_{c=1}^{N} e_c(\bar{t}) > \bar{E} \) ensures \( \rho(t, \bar{E}) > 0 \) when \( t_c = \bar{t}, \forall c \), hence it must also be positive for any other possible tax vector. □

Proof of Proposition 5

(i) For any two countries \( a \) and \( b \) and taking the set \( \hat{t}_{i \notin \{a,b\}} = \{ \hat{t}_i; i \notin \{a,b\} \} \) as given, we may rewrite (??) for countries \( a \) and \( b \)

\[
\Phi(\hat{t}_a, \hat{e}_a, \hat{t}_b, \hat{t}_{i \notin \{a,b\}}) = (1 - \gamma)\hat{e}_a + \hat{t}_a e_a'(1 + \hat{\rho}_a) - \hat{\rho}_a (\gamma(\hat{e}_a - \alpha\hat{e}_a) - (1 - \alpha)\hat{e}_a) = 0
\]

\[
\Phi(\hat{t}_b, \hat{e}_b, \hat{t}_a, \hat{t}_{i \notin \{a,b\}}) = (1 - \gamma)\hat{e}_b + \hat{t}_b e_b'(1 + \hat{\rho}_b) - \hat{\rho}_b (\gamma(\hat{e}_b - \alpha\hat{e}_b) - (1 - \alpha)\hat{e}_b) = 0
\]

Now take \( \bar{e}_a < \bar{e}_b \), and suppose that \( \hat{t}_a < \hat{t}_b \). Then, we have that \( \hat{e}_a > \hat{e}_b \) and, by definition of the Nash Equilibrium, \( \Phi(\hat{t}_a, \bar{E}_a, \hat{t}_b, \hat{t}_{i \notin \{a,b\}}) = 0 \). Now using, successively, concavity of the payoff functions, strategic complementarity, and, Lastly, the fact that \( \partial \Phi(\cdot) / \partial \bar{e}_c < 0 \) we may write

\[
0 = \Phi(\hat{t}_a, e_a, \hat{t}_b, \hat{t}_{i \notin \{a,b\}}) > \Phi(\hat{t}_b, e_a, \hat{t}_b, \hat{t}_{i \notin \{a,b\}}) > \Phi(\hat{t}_b, e_a, \hat{t}_a, \hat{t}_{i \notin \{a,b\}}) > \Phi(\hat{t}_b, e_b, \hat{t}_a, \hat{t}_{i \notin \{a,b\}}) = 0
\]

And a contradiction is reached. □