THE USE OF OVERLAPPING ECONOMIC INSTRUMENTS IN CARBON EMISSIONS REGULATION IN A SMALL ECONOMY

Mercedes de Miguel Cabeza

Abstract

In 2005 the European Union introduced an emissions trading system for energy-intensive installations of some sectors. In order to achieve their overall emissions reduction commitments, Member States are required to introduce additional domestic measures. In this paper we investigate the economic effects of the use of overlapping economic instruments in a small economy, which has to comply with a given emission-reduction commitment, without changing the design of the emissions trading system. The introduction of an additional emissions tax on sectors covered by the emissions trading scheme leads to an efficiency loss. For those sectors which do not participate in the permits market but have to comply with an emissions reduction target, the introduction of an emissions tax would only be one mechanism of achieving its exogenously given commitment at a minimum cost. By means of a partial equilibrium model, we quantify in different scenarios the costs of achieving the commitment in Aragon, a Spanish region in which a tax on emissions was introduced recently.

JEL classification: H23 (Externalities; Redistributive Effects; Environmental Taxes and Subsidies), Q58 (Government Policy).

Keywords: Emissions trading, Environmental taxes, National Allocation Plans

Correspondence: Cologne Center for Public Economics, University of Cologne
P.O. Box 42 05 20, 50899 Cologne, Germany
e-mail: deMiguel-Cabeza@fifo-koeln.de

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1. INTRODUCTION

Under the Kyoto Protocol, the European Union committed itself to reduce its greenhouse gases emissions by 8% between 2008 and 2012 with respect to the emissions of 1990. This joint commitment was distributed between Member States by the *European Burden Sharing Agreement* (BSA)[1]. With the purpose of allowing Member States to reach their emissions reduction commitments in an efficient way, the European Union introduced in 2005 an EU-wide emissions permits trading system[2], which constitutes the main instrument of the European environmental policy. However, the present system only covers certain installations of energy-intensive sectors. In order to reach their overall emissions-reduction commitments, Member States must introduce or maintain complementary domestic abatement policies, such as energy or emissions taxes[3]. As a result, some sectors could be simultaneously regulated by several instruments with similar policy objectives.

Some relevant research has been carried out into the conditions under which the use of multiple environmental policy instruments is preferable to the application of a single policy instrument[4]. The interactions between the *European Emissions Trading Scheme* (EU-ETS) and particular national regulations have also been described in different studies[5]. However, little (theoretical work and) simulations have been done on the issue[6]. This paper analyses the effects of introducing a carbon emissions tax in a small economy participating in the European trading system, which has to comply with an emissions-reduction commitment. By means of a partial equilibrium model, we quantify the costs of achieving the commitment of Aragon, a Spanish region where a tax on carbon emissions has been introduced recently[7], in different policy mix scenarios.

The paper is structured as follows. In section 2, we briefly describe the characteristics of the problem and delimit the purpose of the study. Section 3 presents the algebraic model followed by the specifications for the scenarios and cases analysed in section 4. In section 5,

[1] EU (2002).
[2] EU (2003).
[3] Fiscal policy is one of the few issues requiring unanimity in the European Council. This condition would remain, even if the Constitutional Treaty were finally approved. Differences in energy or emissions taxation across Member States are important, despite of efforts.
[4] See, for example, Gawel (1991), Johnstone (2003 and 2006).
[5] For a discussion of the German case, see Bertenrath et al (2007), Böhringer et al (2005 a), Heilmann (2005).
[6] Böhringer et al (2006 a) analyse the efficiency losses from a simultaneous application of the EU-ETS and emissions taxes imposed on energy-intensive sectors within a partial equilibrium framework for the EU; Veenendaal (2006) focuses on the interactions between the EU-ETS and pre-existing energy taxes.
[7] Gobierno de Aragón (2005).

we present the results of the simulations. The last section concludes and summarizes the main results.

2. PURPOSE OF THE STUDY

The EU-wide emissions trading scheme constitutes the largest “cap-and-trade” system in the world. In a trading system, industries with high abatement costs (marginal abatement cost function *H* in figure 1), will decide to abate less than they are committed to and buy permits in the market. On the contrary, emitters with low abatement costs (*L* in figure 1), will prefer to reduce their emissions (for example by investing in cleaner technologies), and sell the remaining permits on the market. As a result, in the equilibrium all emitters will have the same marginal abatement costs and emissions abatement will be undertaken at the lowest possible cost.

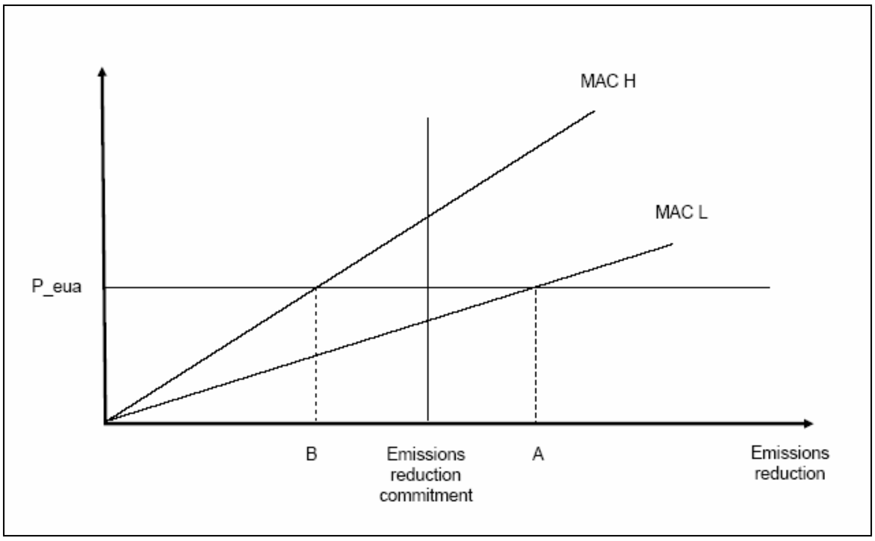

Figure 1. Uniform marginal abatement costs of all emitters in an emissions trading system.

However, the EU-ETS is still in its start phase[8] and its scope is limited. At present, the system only covers installations of energy-intensive sectors with a capacity exceeding 20 MW[9]. They account together for around 45% of the EU’s total CO_2 emissions, and about 30% of its overall greenhouse gas emissions[10]. Every Member State has to present a National Allocation Plan for each trading period, subject to the approval by the European Commission. In these Plans, Member States establish the total number of allowances to be allocated to

[8] The first trading period (2005-2007) has been aimed to gain experience in this kind of instrument, whereas the commitments under the Kyoto Protocol have to been achieved during the second trading period (2008-2012).

[9] The EU-ETS covers energy activities (combustion installations with a rated thermal input exceeding 20 MW, mineral oil refineries, coke ovens), production and processing of ferrous metals (metal ore and steel installations), mineral industry (cement kilns, glass and ceramics manufacturing), as well as paper, pulp and board mills (EU, 2003).

[10] EU (2005).

those sectors participating in the trading system, as well as their distribution between individual plants. At present, emissions allowances are allocated mostly for free[11].

The remaining emissions reduction up to the overall commitment is calculated as the difference between the reduction commitment for the whole economy, and the total number of allowances allocated to those sectors covered by the trading system. This remaining abatement target has to be achieved through domestic abatement instruments, proposed in the National Allocation Plans, such as fiscal measures, funding programmes and administrative regulations (figure 2). The present paper focuses on the interactions between the EU-ETS and a tax on emissions introduced in a small economy.

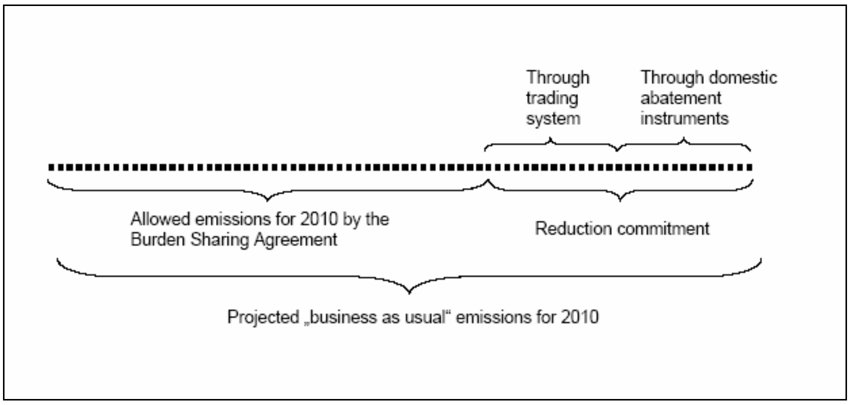

Figure 2. Distribution of the emissions reduction commitment between sectors covered and non-covered by the EU-ETS.

From an environmental point of view, the joint implementation of both instruments is not justified. Given the existence of a tradable permits system, the introduction of a tax on carbon-dioxide emissions will not contribute to any additional environmental benefits. The reason is that the emissions reduction target is established ex-ante by the permits trading system. An additional tax will be compensated by a lower permit price, unless the tax is high enough to render the cap-and-trade system redundant. If the tax only covered a small part of the economy, the permit price would not decrease significantly. The installations covered by both instruments would reduce their emissions and export more permits than without the tax, but the emissions cap of the whole system would remain unchanged.

In a recent paper, Böhringer et al (2006 a) analyse the interactions between the present EU-ETS and a hypothetical emissions tax on sectors covered by the trading system, when the tax is only levied in one or several countries. They conclude that, even assuming over-

[11] In the second phase (2008-2012), a larger number of Member States will auction off parts of their ET budget compared to phase I (2005-2007). However, the shares will be well below the maximum share of 10% allowed by the European Directive (Betz et al, 2006). For a review of the debate about the advisability of auctioning or grandfathering the allowances, see for example Hepburn et al (2006).

allocation to the sectors covered by the EU-ETS, the additional tax would cause inefficiencies[12].

Johnstone (2006) points out other reasons for a joint application of tradable permits and environmentally-related taxes. First, a tax can act as a cap on permit prices, reducing compliance-cost uncertainty (“safety valve” argument)[13]. If the tax is high enough, it can serve as a penalty for non-compliance. Furthermore, when the permits are allocated for free, as it is the common case in the EU-ETS, firms receive a windfall rent equal to the value of the permits allocated. If the tax is complementary to the trading system (not a substitute), it can be used to recover windfall profits.

By means of a partial-equilibrium model, we calculate the cost for a small economy of complying with a given commitment in two policy-mix scenarios. Except for the reference scenario, we take into account that a small region or state cannot modify the distribution set at the *European Burden Sharing Agreement*[14] or the design of the EU-ETS. First, we consider a fictitious situation in which every sector can participate in the emissions trading system in order to achieve the overall emissions-reduction target, but no tax is introduced. As the market would lead to the lowest possible cost, we consider it as our reference scenario (scenario *Opt*). Secondly, we describe a situation in which only some industries are covered by the emissions trading system, as occurs in the European Emissions Trading Scheme, while the public agent of the small region or state considered introduces an emissions tax, whose tax rate can vary across sectors (scenario *Mix*). In this case, our aim is to calculate which tax rates would lead to the lowest cost. Thirdly, we calculate the cost of achieving a given commitment in two specific cases of the second scenario. In the first case we impose tax rates equal to zero, as happens in many Member States and regions, which have not introduced any carbon emissions tax (scenario *Mix_NoTax*). The second case represents the current situation of a Spanish region, Aragon, where a tax on emissions has been recently introduced (scenario *Mix_Aragon*).

In absence of any specific instrument, we assume that the region achieves its commitment through a fictitious ideal instrument, whose cost is measured by an abatement

[12] They demonstrate that a large economy could benefit from the introduction of an additional tax, if „the lower import price for permits and the reduced amount of permits to be imported compensate the increased abatement efforts“. However, they notice that the conditions seem to be very restrictive.
[13] In the same way, a subsidy can act as a lower bound.
[14] This assumption is relevant for many small EU-Member States, especially after the enlargement of the Eastern European countries in 2004 and 2007.

cost function[15]. Apart from it, the public agent can introduce a trading system, an additional tax on emissions, or both instruments. In presence of these specific instruments, emitters decide their emissions level comparing the costs of the instruments with the costs of abatement (our fictitious ideal instrument).

It is convenient to remark that the use of a partial model does not permit to analyse issues such as market interactions, spill-over effects or revenue-recycling. Market distortions are, moreover, not considered in the following.

3. ALGEBRAIC MODEL

In this section we set up a partial equilibrium model in order to analyse the effects of using overlapping economic instruments in carbon emissions regulation. We focus on a small economy, which has to comply with a given emissions reduction commitment and works as a price taker at the emissions permits trading system. Following the nomenclature by Böhringer et al (2005 b), we consider two sectors, *DIR* (*directive*) and *NDIR* (*no directive*). *DIR* consists of those industries participating in the emissions permits trading system, whereas *NDIR* includes the remaining economic industries. The public agent's aim is to minimize the total social cost of achieving the emissions reduction requirement as established exogenously, in the policy mix scenarios described above.

One has to keep in mind that the results will be efficient, only in the sense that the cost of achieving the given emissions reduction requirement, will be minimized. The overall reduction requirement, as well as its distribution between sectors (except in the reference scenario, *Opt*), are given and cannot be changed by the public agent of the economy. The only decision variable is, therefore, the tax on emissions. This is a main difference with respect to those models which assume the public agent to be able to change the design of the emissions permits trading system.

Let *target* be the difference between the projected *business as usual* and the allowed emissions for 2010[16], being *ß* the reduction requirement for our region as established at the *Burden Sharing Agreement* (in percentage) (figure 3):

[15] The marginal abatement cost (*MAC*) functions for both kinds of sectors are taken from Böhringer et al (2006 b). By means of a general equilibrium model, they generate a sequence of marginal abatement costs (carbon taxes) and the associated emissions reductions, and obtain the coefficients of a polynomial of third degree applying a least-square method. The *MAC* functions derived in this way represent, therefore, a situation in which the emissions reduction is implemented cost efficiently by efficient emissions taxes.

[16] It is commonly supposed that the commitment hat to be reached in 2010. This convention assumes a lineal evolution of the emissions between 2008 and 2012.

$$target = e_{TOT}^{2010} - e_{BSA}^{2010} \quad (1)$$

with

$$e_{BSA}^{2010} = e_{TOT}^{1990} \cdot (1 - \beta) \quad (2)$$

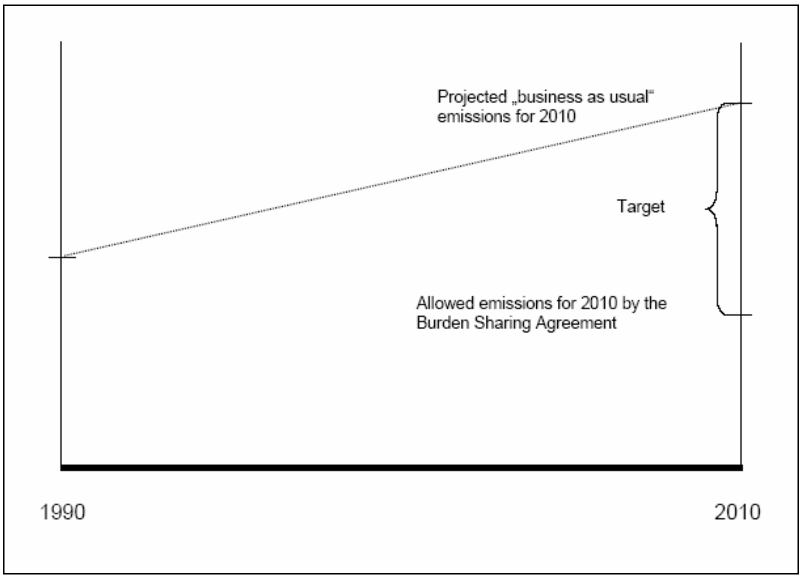

Figure 3. Emissions reduction target for the whole economy in 2010.

Every sector has to achieve its own commitment in order to achieve the total *target*:

$$target = target_{DIR} + target_{NDIR}, \quad (3)$$

where $target_{DIR}$ is calculated as the difference between the projected *business as usual* emissions of the sector *DIR* and the sum of the allowances allocated to it by the National Allocation Plan:

$$target_{DIR} = e_{DIR}^{2010} - e_{DIR}^{NAP} \quad (4)$$

following:

$$target_{NDIR} = target - target_{DIR} = e_{NDIR}^{2010} - \left(e_{BSA}^{2010} - e_{DIR}^{NAP}\right) \quad (5)$$

In order to achieve their commitments, every sector can decide between reducing their emissions and buying permits in the market (*European Union Allowances*):

$$target_i = abate_i + m\_eua_i \quad (6)$$

being $target_i$ the total commitment for the sector *i* (*i* = *DIR*, *NDIR*), $abate_i$ the abatement by sector *i* and m_eua_i its net imports of permits[17]. Whereas the sector *DIR* always

[17] Besides the *European Union Allowances*, *eua*, emitters can buy *cdm* (*Clean Development Mechanism*) or *ji* (*Joint Implementation*) permits. The *Clean Development Mechanism* allows governments to implement

participates in the permits market, the sector *NDIR* can only use permits in the first scenario. Therefore the net imports by sector *NDIR*, m_eua_{NDIR} only will be different from zero in the first scenario, otherwise will be zero.

Let j be a representative installation of sector i. In absence of any restriction, installation j would emit e_{ij}^{2010} units. In presence of the emissions permits trading system, installation j receives e_{ij}^{NAP} permits, which can be traded on the market. The difference between e_{ij}^{2010} and e_{ij}^{NAP} can be considered as its specific target. In order to achieve it, emitter j can reduce its emissions or buy (or sell) permits on the market:

$$target_{ij} = abate_{ij} + m\_eua_{ij}$$

being $abate_{ij}$ the emissions reduction achieved by emitter j, and m_eua_{ij} its net imports of permits.

The cost of the abatement achieved by installation j through our fictitious ideal instrument, is given by the abatement cost function of sector i:

$$AC_{ij} = AC_i\left(abate_{ij}\right)$$

such that:

$$AC'_i\left(abate_{ij}\right) = MAC_i\left(abate_{ij}\right) = a_{i1} \cdot abate_{ij} + a_{i2} \cdot abate_{ij}^2 + a_{i3} \cdot abate_{ij}^3 \qquad (7)$$

Furthermore, emitters have to pay a tax on its final level of emissions, t_i. Taking into account the opportunity cost of the allocated permits, the cost for emitter j of its final level of emissions is:

$$\left(e_{ij}^{NAP} + m\_eua_{ij}\right) \cdot \left(p\_eua + t_i\right) = e_{ij} \cdot \left(p\_eua + t_i\right)^{18},$$

emissions-reduction projects in developing countries, which have no targets under the Protocol, and count the reductions against their own Kyoto targets. In a similar way, governments can implement projects in other industrialised countries with Kyoto targets (*Joint Implementation*). In order to avoid the excessive use of permits *cdm* and *ji*, the Directive (EU, 2003) establishes that the majority of the emissions reduction should be made inside the European Union. The allowed percentages of *cdm* and *ji* permits with respect to the total emissions permits are set up in the National Allocation Plans. Low percentages could lead to an excess of certified *cdm* or *ji* permits in the market, and their prices (*p_cdm*, *p_ji*), would be lower than the price of the permits *eua*, *p_eua*. However, at the present time that seems most improbable to happen, so we assume *p_cdm* and *p_ji* to be equal to *p_eua*. As a consequence, the distinction between *cdm*, *ji* and *eua* turns to be unnecessary, since it does not affect to the reduction cost. We assume, moreover, that the regional market is perfectly integrated in the European market and all permits are traded at the price *p_eua*. Therefore it is not necessary to consider any specific domestic permits market.

[18] $e_{ij}^{NAP} + m\_eua_{ij} = e_{ij}^{2010} - target_{ij} + m\_eua_{ij} = e_{ij}^{2010} - abate_{ij} - m\_eua_{ij} + m\_eua_{ij}$

where e_{ij} is the final emissions level of emitter *j* and *p_eua* is permits market price. Because of the small size of the economy, we assume *p_eua* to be exogenous.

Therefore, installation *j* faces the following decision problem:

$$\underset{abate_{ij}}{Min}\ TC_{ij} = AC_i\left(abate_{ij}\right) + e_{ij}\cdot\left(p\_eua + t_i\right) =$$

$$= AC_i\left(abate_{ij}\right) + \left(e_{ij}^{2010} - abate_{ij}\right)\cdot\left(p\_eua + t_i\right) \qquad (8)$$

We derive the first order condition:

$$\frac{dTC_{ij}}{dabate_{ij}} = MAC_i\left(abate_{ij}\right) - \left(p\_eua + t_i\right) = 0\ ,$$

following:

$$\boxed{MAC_i\left(abate_{ij}\right) = p\_eua + t_i} \qquad (9)$$

I.e., installation *j* decides its abatement level such that the marginal abatement cost at that abatement level equals the sum of the permit price and the tax rate.

In a further step, the decision-making agent minimizes the total social cost for all installations of sector *i*:

$$\underset{abate_{ij}}{Min}\ TSC_i = \sum_j AC_i\left(abate_{ij}\right) + p\_eua\cdot\sum_j e_{ij} =$$

$$= \sum_j AC_i\left(abate_{ij}\right) + p\_eua\cdot e_i^{2010} - p\_eua\cdot\sum_j abate_{ij} \qquad (10)$$

Following the first order conditions:

$$\frac{\partial L}{\partial abate_{ij}} = MAC_i\left(abate_{ij}\right) - p\_eua = 0\ , \qquad \forall\, j \in i,$$

resulting:

$$\boxed{MAC_i\left(abate_{ij}\right) = p\_eua} \qquad \forall\, j \in i \qquad (11)$$

From expressions (9) and (11), it follows that, in order to achieve an efficient solution from a social point of view, every emitter should decide its abatement level such that the marginal abatement cost function equals the permit price, i.e. no emissions tax should be introduced on those companies participating in the emissions permits trading system.

Figure 4 illustrates the efficiency loss caused by the introduction of an emissions tax in presence of an emissions permits trading system. We suppose an emissions reduction commitment for sector *i* δ^{NAP}, such that the marginal abatement cost is higher than the permit price, *p_eua*. In absence of a tax, the *DIR* sector would reduce its emissions between *0* and *A*, and import permits from *A* up to δ^{NAP}, at a total cost represented by the areas *0 A B* (abatement cost) and *A B C* δ^{NAP} (import of permits). If the government decides to introduce an additional tax on emissions, emitters make their decision taking into account the tax rate, t_i. They prefer to abate more than δ^{NAP} and export permits at a price *p_eua*, up to the point *D*, where the final price $\left(p\_eua + t_{DIR}\right)$ equals the marginal abatement cost. In this case, the total cost for the sector *i* is represented by the areas *0 D E* (abatement cost) minus the areas δ^{NAP} *C G D* (permits export) and *A B C* δ^{NAP} (avoided permits import). Emitters of sector *i* also pay the tax (area *G E I H* [19]). Even if the tax revenue is refunded, the introduction of a tax induces the sector *i* to reduce its emissions beyond the efficient level, giving rise to a net cost represented by the area *B E G*.

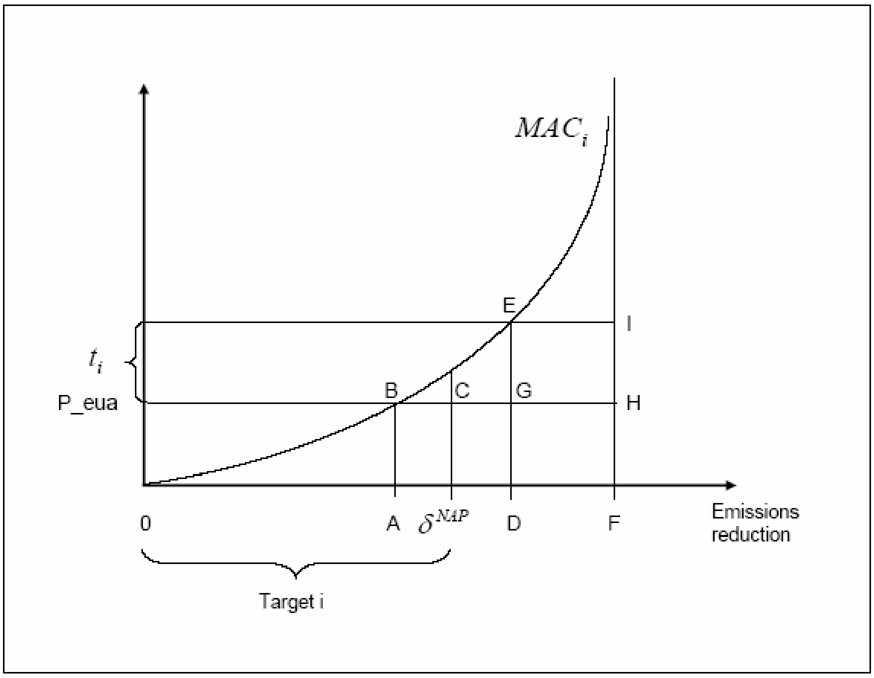

Figure 4. Scenario Opt.

[19] *F* represents the situation in which the emissions of sector *DIR* would be zero. Therefore, sector *DIR* would have to pay the tax rate on its final emissions level, *D* to *F*.

4. Scenarios

In this section, the general model is applied to the policy-mix scenarios explained above.

Scenario *Opt*

In our first scenario (*Opt*), the initial distribution of emissions reduction targets between *DIR* and *NDIR*, set up by the National Allocation Plan, does not affect the total social cost of the region, since both sectors are covered by the permits trading system. Unlike the scenario *Mix*, in which the sector *NDIR* does not participate in the trading system, in scenario *Opt* the resulting emissions of sector *NDIR* can be higher than the target.

We consider an initial over allocation to sector *DIR* (δ^{NAP} in figure 5)[20]. Given the permit price, each sector will abate its emissions as long as the marginal abatement cost is lower than the permit price (*0_DIR* to *A* and *0_NDIR* to *B*). In our case, sector *DIR* sells permits at the market (δ^{NAP} to *A*), whereas sector *NDIR* buys permits (*B* to δ^{NAP}). Compared to a situation without emissions trading, sector *DIR* obtains an efficiency gain represented by the area *C D E* (difference between its abatement cost, *0_DIR A C* and its revenue from selling permits, δ^{NAP} *A C D*. Sector NDIR also obtains an efficiency gain compared to a situation without trading (area *D F G*).

[20] NAPs approved for the first period (2005-2007) have been criticised for having been too generous to installations covered by the EU-ETS. The publication of the verified emissions for the year 2005 showed that installations covered by the EU-ETS had been allocated more permits than they actually needed, following a crash in the permit price.

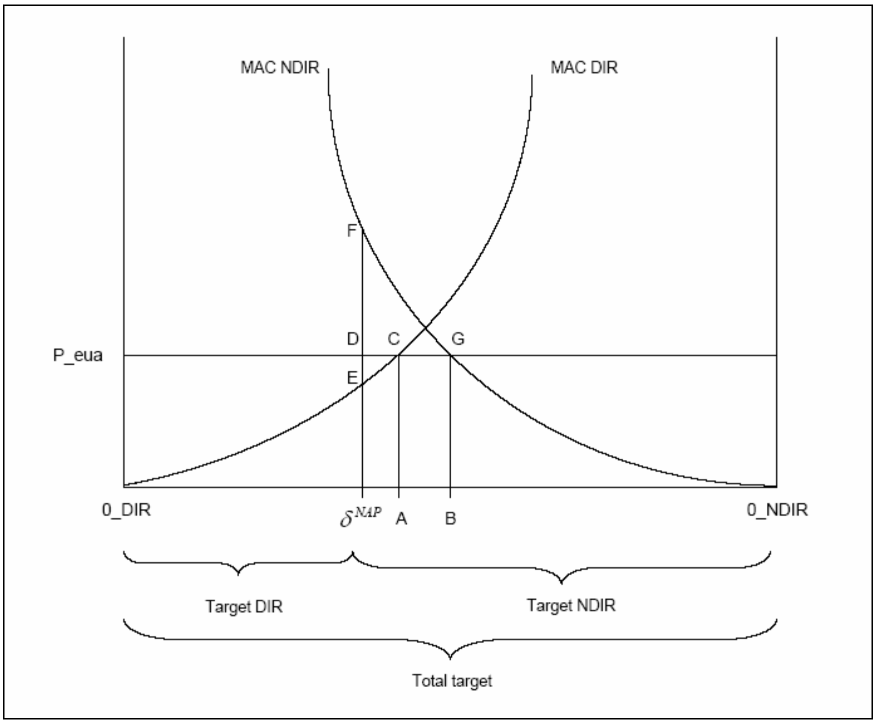

Figure 5. Scenario Opt.

SCENARIO *MIX*

In scenario *Mix* we suppose that the sector *NDIR* does not participate in the permits market, as happens in the current EU-ETS. As a result, the only possibility for sector *NDIR* to achieve its target is reducing its emissions, in the amount derived from the National Allocation Plan ($target_{NDIR} = abate_{NDIR}$). As the amount of emissions to be reduced is given, the abatement costs for sector *NDIR* are derived from the abatement cost function and cannot be optimized (area δ^{NAP} *I 0_NDIR* in figure 6). The introduction of a tax on emissions by the sector *NDIR* would only be a mechanism of achieving the attempted level of abatement, but it cannot improve the efficiency of the system. As for sector *DIR*, we have seen in section 3 that the introduction of a tax on emissions leads to an efficiency loss. In figure 6, the efficiency loss caused by the introduction of an emissions tax in presence of an emissions trading scheme is represented by the area *B E G*.

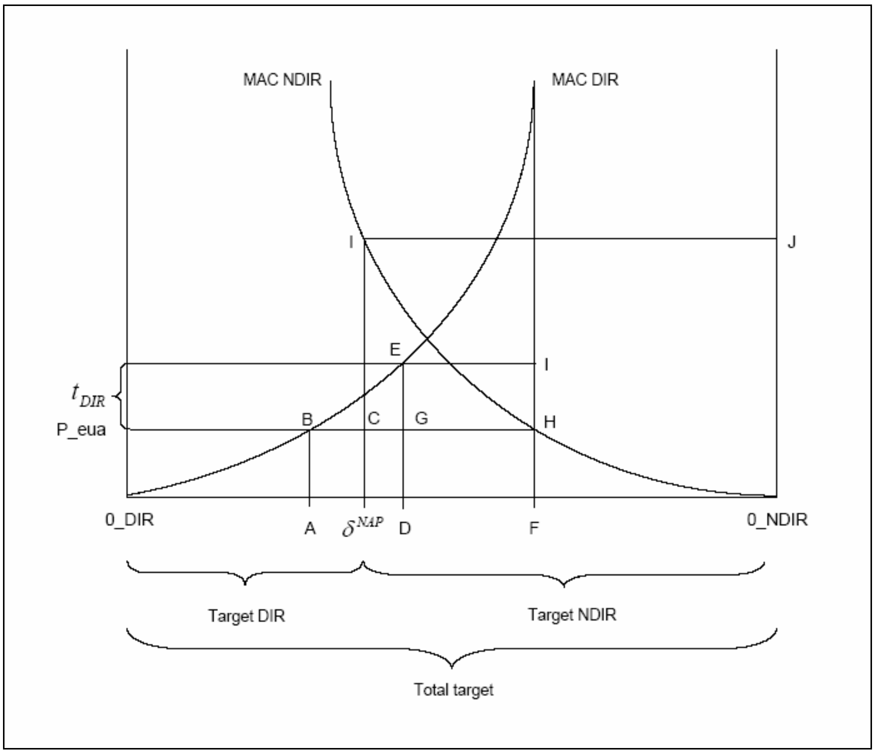

Figure 6. Scenario *Mix*.

We also consider two specific cases of scenario *Mix*. The first application, *Mix_NoTax*, represents the situation of some Member States and regions, which participate in the European emissions trading system, but no complementary tax is levied on those sectors covered by the scheme. In our second application, *Mix_Aragon*, we consider a situation in which the EU-ETS coexists with a CO_2-emissions tax on both sectors, as happens in the Spanish region Aragon[21]. The tax was introduced in 2006 and is levied on the emissions of sulphur oxides, nitrogen oxides and carbon dioxide. The tax rate is 0,2 euros per ton of CO_2[22] for both sectors. However, installations of the *DIR* sector do not pay the tax on those emissions exceeding the cap assigned by the National Allocation Plan. As we can see in figure 7, emitters of sector *DIR* face a discontinuous aggregated marginal cost function:

$p\_eua + t_{DIR}$ for emissions up to $e_{DIR,j}^{NAP}$

p_eua from $e_{DIR,j}^{NAP}$

[21] Gobierno de Aragón (2005), de Miguel Cabeza, M. (2005).

[22] In order to take into account the exemption in the Aragonese tax concerning the combustion of biomass and biofuels, the limit of 100 kilotons per year exempted of taxation, as well as the deduction for investments in measures against pollution, it would be necessary to work with disaggregated data, with are not disposable at this moment. This simplification can be considered acceptable considering the relatively low tax payment compared to the permit price, but could be a research field for the future.

In order to illustrate the decision making process of emitters covered by the EU-ETS, we consider an emitter, *j*, with an initial allocation of permits $e^{NAP}_{DIR,j}$. First, we assume $MAC_{DIR,A}$ to be the relevant marginal abatement cost function for emitter *j*. In this case, emitter *j* faces a minimization problem as illustrated in section 3, following the first order condition:

$$\boxed{MAC_{DIR}\left(abate_{DIR,j}\right) = p\_eua + t_{DIR}} \qquad (=9)$$

In this case, emitter *j* makes its decision taking into account the permit price as well as the tax rate. Secondly, we suppose $MAC_{DIR,B}$ to be the marginal abatement cost function of emitter *j*. In this case, emitter *j* only considers the permit price:

$$\underset{abate_{DIR,j}}{Min}\ TC_{DIR,j} = AC_{DIR}\left(abate_{DIR,j}\right) + e_{DIR,j} \cdot p\_eua + e^{NAP}_{DIR,j} \cdot t_{DIR} =$$

$$= AC_{DIR}\left(abate_{DIR,j}\right) + \left(e^{2010}_{DIR,j} - abate_{DIR,j}\right) \cdot p\_eua + e^{NAP}_{DIR,j} \cdot t_{DIR}$$

following:

$$\boxed{MAC_{DIR}\left(abate_{DIR,j}\right) = p\_eua} \qquad (12)$$

However, if the relevant marginal abatement cost function is $MAC_{DIR,C}$, we cannot determine the emissions level of emitter *j* as there are two cross points with the total price function.

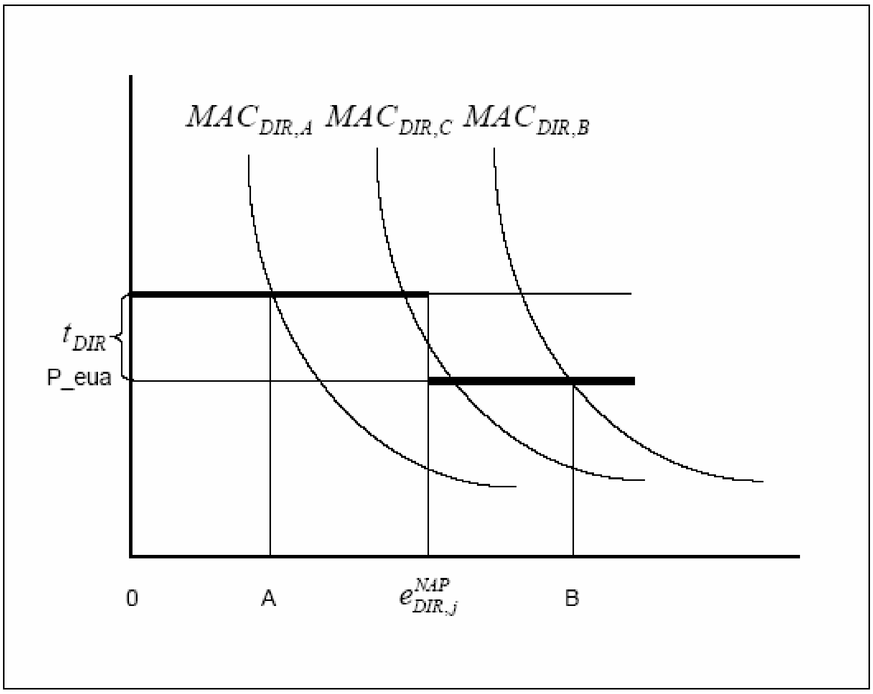

Figure 7. Scenario *Mix_Aragon*.

In order to consider how installations covered by the EU-ETS make their decisions taking into account this exception, it would be necessary to consider disaggregated data on emissions, targets and marginal abatement cost functions for every emitter. As this information is not available, we consider in our simulations a single marginal abatement cost function, representative for the whole *DIR* sector.

5. SIMULATIONS

The model illustrates the carbon market of the Spanish region Aragon. As explained before, we consider the emissions reduction commitment and the design of the European Emissions Trading Scheme as given. The only policy instrument available for the regional government is, therefore, a tax on carbon emissions. In order to quantify the costs of achieving the emissions reduction commitment in the different scenarios, it has been necessary to make some assumptions concerning the marginal abatement cost functions, the emissions data, the permits allocation to the *DIR* sector, and the carbon permit price. These assumptions are explained in the appendix. In a first step we run simulations using those data which represent the situation of Aragon most accurately. In a second step we run alternative simulations changing the data assumed.

Table 1 reports the assumptions considered in every simulation, starting with the most accurate for Aragon in the first column (reference simulation). In this case, the emissions generated by sector *DIR* represent a high percentage of the total emissions of Aragon (68,25%), compared to the European average (approximately 45%). This fact affects our results as we explain below. In the second simulation we consider a lower percentage of emissions covered by the EU-ETS (45%). The resulting target for sector *DIR* is lower, as it is considered to be the case in most European countries. In the third and forth simulations we consider a lower permit price[23] and a higher tax rate respectively, maintaining the rest of the assumptions as in the first simulation.

[23] More similar to the permit price for permits tradable in the period 2005-2007, which has decreased continually since May 2006.

Table 1. Data assumed in the simulations.

		Reference simulation	Second simulation: lower percentage of emissions by *DIR*	Third simulation: lower permit price	Forth simulation: higher tax rate
2010 allowed emissions (*Burden Sharing Agreement*)*		14,25	14,25	14,25	14,25
2010 projected emissions (*business as usual*)*	DIR sector	14,01 (68,25)	9,24 (45,00)	14,01 (68,25)	14,01 (68,25)
	NDIR sector	6,52 (31,75)	11,29 (55,00)	6,52 (31,75)	6,52 (31,75)
	Total economy	20,53	20,53	20,53	20,53
Permits allocated to *DIR* by the National Allocation Plan*		8,02	8,02	8,02	8,02
Target*	DIR sector	5,99 (95,39)	1,22 (19,40)	5,99 (95,39)	5,99 (95,39)
	NDIR sector	0,29 (4,61)	5,06 (80,60)	0,29 (4,61)	0,29 (4,61)
	Total economy	6,28	6,28	6,28	6,28
Permit price**		22,8	22,8	3	22,8
Tax rate**		0,2	0,2	0,2	1

(*)Mt CO_2. Percentages respect to the total projected emissions in brackets. (**) € / ton CO_2.

The main results obtained in the simulations are reported in tables 2 and 3. As the efficient level of the tax rates is zero, the results obtained for the general scenario *Mix* coincide with those for the first specific case, *Mix_NoTax*, where no tax is introduced by the regional government. For this reason, results for scenario *Mix* are not specified in the following. Social costs in the last column include the costs caused by the emissions reductions, and the opportunity costs of the emissions, but not the tax payments, which are supposed to be returned to society. Table 2 shows the results of the simulation carried out with the most accurate data for Aragon. In absence of a tax, sector *DIR* reduces its emissions by 18% respect to its projected emissions level (42,19 % of its target) and buys permits in the market in order to achieve its target. As the tax rate is low compared to the permit price, the introduction of the exogenous tax in *Mix_Aragon* hardly changes the behaviour of sector *DIR*. For this reason, the social cost of sector *DIR* remains constant after the introduction of the tax in scenario *Mix_Aragon*. The marginal abatement cost of sector *DIR* equals the permit price, plus the tax rate in scenario *Mix_Aragon*. In scenario *Opt*, sector *NDIR* reduces its emissions above its target, and sells permits in the market. In the other scenarios, *NDIR* cannot trade in the market and reduces its emissions up to the target. Except for scenario *Opt*, the marginal abatement cost for sector *NDIR*, determined by the given emissions reduction commitment, is lower because of its low target. The social cost of the sector *NDIR* is slightly higher in scenarios *Mix_NoTax* and *Mix_Aragon*, because it does not benefit from trading in the market. The social costs for the whole economy and their distributions between sectors are very similar in every scenario. As the target to be achieved by the installations covered by the EU-ETS is high, the extension of the market to the whole economy does not lead to a significant decrease of the total social cost. Furthermore, the introduction of a tax on emissions does not lead to an important increase in the total social cost, as the tax rate is low compared to the permit price.

Table 2. Reference simulation.

		Emissions reduction*	**Emissions reduction (in percentage)****	**Net import of permits***	**Marginal abatement cost*****	**Tax rate*****	**Social cost******
Opt	DIR sector	2,53 (42,19)	18,04	3,46	22,80	-	285,30 (67,35)
	NDIR sector	0,85 (293,99)	13,07	-0,56	22,80	-	138,34 (32,65)
	Total economy	3,38 (53,80)	16,46	2,90			423,64
Mix_NoTax	DIR sector	2,53 (42,19)	18,04	3,46	22,80	-	285,30 (66,61)
	NDIR sector	0,29 (100,00)	4,47	-	6,86	-	142,99 (33,39)
	Total economy	2,82 (44,88)	13,73	3,46			428,29
Mix_Aragon	DIR sector	2,54 (42,40)	18,13	3,45	23,00	0,20	285,30 (66,61)
	NDIR sector	0,29 (100,00)	4,47	-	6,86	0,20	142,99 (33,39)
	Total economy	2,83 (45,09)	13,80	3,45		0,20	428,29

(*) Mt CO2. Percentages respect to targets in brackets. (**) In percentage respect to the 2010 projected business-as-usual emissions. (***) Euros 2006 / ton CO2. (****) Millions Euros 2006. Percentages of the total social cost in brackets.

Table 3 reports the main results for the alternative simulations. When we consider a lower target to be achieved by the installations covered by the trading system (second simulation), sector *DIR* exports permits to the market, reducing its social cost compared to the reference simulation. On the contrary, sector *NDIR* buys permits in order to achieve its target, incurring in a higher social cost. As a result, the social cost for the whole economy remains as in the reference simulation, but the distribution between sectors changes. The marginal and social costs of sector *NDIR* in scenarios *Mix_NoTax* and *Mix_Aragon* are significantly higher than in scenario *Opt*, as it cannot benefit from trading. They are also higher than in the other simulations, because of the increase in the target assumed to be achieved by sector *NDIR.* As in the reference scenario, the introduction of a tax in *Mix_Aragon* does not change the results significantly. A lower permit price (third simulation) serves as a disincentive to reduce emissions for those sectors participating in the trading scheme. Both sectors face lower social costs, as the opportunity costs reflects the lower permit price. Finally, a higher tax rate (forth simulation, scenario *Mix_Aragon*) leads to a low increase in the emissions reduction by sector *DIR*, but the tax rate remains low compared to the permit price.

Table 3. Alternative simulations.

		Emissions reduction*	**Emissions reduction (in percentage)****	**Net import of permits***	**Marginal abatement cost*****	**Tax rate*****	**Compliance cost******
Second simulation: lower percentage of emissions generated by sector *DIR*							
Opt	DIR sector	2,53 (207,44)	27,36	-1,31	22,80	-	176,51 (41,67)
	NDIR sector	0,85 (16,83)	7,54	4,21	22,80	-	247,13 (58,33)
	Total economy	3,38 (53,80)	16,46	2,90			423,64
Mix_NoTax	DIR sector	2,53 (207,44)	27,36	-1,31	22,80	-	176,51 (18,68)
	NDIR sector	5,06 (100,00)	44,84	-	342,09	-	768,65 (81,32)
	Total economy	7,59 (120,84)	36,97	-1,31			945,17
Mix_Aragon	DIR sector	2,54 (208,52)	27,50	-1,32	23,00	0,20	176,51 (18,68)
	NDIR sector	5,06 (100,00)	44,84	-	342,09	0,20	768,65 (81,32)
	Total economy	7,60 (121,05)	37,04	-1,32		0,20	945,17
Third simulation: lower permit price							
Opt	DIR sector	0,53 (8,88)	3,80	5,46	3	-	41,21 (68,03)
	NDIR sector	0,13 (45,60)	2,03	0,16	3	-	19,36 (31,97)
	Total economy	0,66 (129,05)	3,24	5,62			60,57
Mix_NoTax	DIR sector	0,53 (8,88)	3,80	5,46	3	-	41,21 (67,70)
	NDIR sector	0,29 (100,00)	4,47	-	6,86	-	19,66 (32,30)
	Total economy	0,82 (13,12)	4,01	5,46			60,87

		Emissions reduction*	Emissions reduction (in percentage)**	Net import of permits*	Marginal abatement cost***	Tax rate***	Compliance cost****
Mix_Aragon	DIR sector	0,56 (9,42)	4,03	5,43	3,2	0,20	41,22 (67,70)
	NDIR sector	0,29 (100,00)	4,47	-	6,86	0,20	19,66 (32,30)
	Total economy	0,86 (13,63)	4,17	5,43		0,20	60,88
Forth simulation: higher exogenous tax rate							
Opt	DIR sector	2,53 (42,19)	18,04	3,46	22,80	-	285,30 (67,35)
	NDIR sector	0,85 (293,99)	13,07	-0,56	22,80	-	138,34 (32,65)
	Total economy	3,38 (53,80)	16,46	2,90			423,64
Mix_NoTax	DIR sector	2,53 (42,19)	18,04	3,46	22,80	-	285,30 (66,61)
	NDIR sector	0,29 (100,00)	4,47	-	6,86	-	142,99 (33,39)
	Total economy	2,82 (44,88)	13,73	3,46			428,29
Mix_Aragon	DIR sector	2,59 (43,27)	18,50	3,40	23,80	1	285,33 (66,62)
	NDIR sector	0,29 (100,00)	4,47	-	6,86	1	142,99 (33,38)
	Total economy	2,88 (45,91)	14,05	3,40		1	428,32

(*) Mt CO2. Percentages respect to targets in brackets. (**) In percentage respect to the 2010 projected business-as-usual emissions. (***) Euros 2006 / ton CO2. (****) Millions Euros 2006. Percentages of the total social cost in brackets.

6. CONCLUSIONS

In 2005 the European Union introduced an emissions trading system for energy-intensive installations of some sectors. Member States are expected to introduce additional domestic measures in order to achieve their overall emissions reduction commitments. This paper analyses the economic effects of the use of overlapping economic instruments in a small economy, which has to comply with a given emission-reduction commitment without changing the design of the emissions trading system. This model setting is relevant for many small EU-Member States, especially after the enlargement of the Eastern European countries in 2004 and 2007. We demonstrate algebraically that the introduction of an additional tax on emissions generated by sectors covered by the emissions trading scheme leads to an inefficient result. As the distribution of emissions reduction targets between sectors is exogenously given, the introduction of an emissions tax on sectors which do not participate in the market would only be one mechanism of achieving the exogenously given level of abatement at a minimum cost, but it cannot lead to an efficient solution for the whole system. Nevertheless, some installations in Aragon, a Spanish region in which a tax on emissions was introduced recently, are covered by both instruments, the emissions trading and the emissions tax. On the other hand, numerous emitters do not need to pay the tax at all, due to the minimum emissions boundaries. This is the case of many emitters from sectors not covered by the emissions trading system, such as the transport sector or the agriculture.

By means of a partial equilibrium model, we quantify the costs of achieving the commitment of Aragon. We run simulations for several policy mix scenarios and consider different assumptions on data. As the tax rate is low compared to the permit price, the introduction of this emissions tax hardly serves as an incentive to reduce emissions of the sector participating in the emissions trading system. Furthermore, we find out that the extension of the emissions trading system to the whole economy only leads to a very low decrease of the total social cost. The main reason is that the current EU-ETS already covers a high percentage of the total emissions of Aragon. This result suggests the importance of taking into account the regional differences in the design of the National Allocation Plans, especially the initial distribution of emissions reduction commitments to the regulated and non-regulated sectors.

Quantitative simulations could be improved by considering specific marginal abatement cost functions for Aragon, as well as more specific data. Furthermore, the present work could be extended by using disaggregated data on emissions, in order to take into account the exceptions contemplated in the tax of Aragon.

APPENDIX: ASSUMPTIONS AND DATA

In order to quantify the overall required emissions reduction for 2010 (*target*), we calculate the difference between the projected *business as usual* emissions, and the emissions allowed by the Burden Sharing Agreement for the whole economy. The forecasted total emissions level for Aragon is calculated considering the forecasted emissions level for the whole Spanish economy[24], and the percentage of emissions generated in Aragon compared to

[24] Ministerio de Medio Ambiente, 2006 a.

the total Spanish CO_2-emissions (average of the period 1990-2005)[25]. Furthermore, Spain was allowed to increase its emissions by 15% with respect to its 1990 emissions level by the *European Burden Sharing Agreement*. We assume the region Aragon to have the same commitment as Spain (in percentage).

We also quantify the commitments for every sector, taking into account their projected *business as usual* emissions and the permits allocated to the *DIR* sector. The forecasted emissions for Aragon are disaggregated into both sectors considering the percentage of emissions generated by industries covered by the EU-ETS of the total emissions of Aragon in 2005[26]. This percentage (68,25%) is sensibly higher than in the EU (approximately 45%). The main reason is the presence of some important coal-fired power plants. As a consequence, the target to be achieved by the sector *DIR* is comparatively high, leading to higher costs.

At the moment of finishing this article, the National Allocation Plan 2008-2012 for Spain, approved by the European Commission, includes the total cap of permits to be allocated, but not the allocation of permits to the single installations. We assume that the percentage of permits allocated to installations located in Aragon compared to the total cap, will be the same as in the first period. We calculate such percentage[27] and apply it to the total cap of permits set up by the National Allocation Plan 2008-2012[28].

The permit price considered is the average of the future prices for permits tradable during the second period, 2008 to 2012[29]. This is sensibly higher than the current price for permits tradable during the first period, 2005-2007.

Both sectors, *DIR* (covered by the EU-ETS) and *NDIR* (not covered), are represented by a marginal abatement cost function taken from Böhringer et al (2006 b)[30]. These functions are estimated using data for the whole Spanish economy and cannot be directly applied to sensibly lower data. In order to take into account the specificities of the economic structure of Aragon, we apply a scale to the emissions data calculated for Aragon before running the simulations. The results so obtained are re-scaled afterwards.

[25] Data provided by the Ministry of Environment and Ministerio de Medio Ambiente and Ministerio de Medio Ambiente, 2007 a.

[26] Data provided by the Ministry of Environment and Ministerio de Medio Ambiente and Ministerio de Medio Ambiente, 2006 b.

[27] Ministerio de Medio Ambiente, 2005.

[28] Ministerio de Medio Ambiente, 2007 b.

[29] European Energy Exchange, 2007 (prices available in Mai 2007).

[30] These functions are calculated for the Spanish *DIR* and *NDIR* sectors. We assume that abatement costs functions for both sectors in Aragon are the same as in Spain.

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