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Intra-and Extra-Union Flexibility in Meeting the European Union's Emission Reduction Targets

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Abstract: The EU has proposed four flexibility mechanisms for the regulation of greenhouse gas emissions in the period 2013-2020: (1) the Emissions Trade Scheme (ETS), a permit market between selected companies; (2) trade in non-ETS allotments between Member States; (3) the Clean Development Mechanism (CDM) to purchase offsets in developing countries; and (4) trade in CDM warrants between Member States. This paper shows that aggregate abatement costs fall as flexibility increases. However, limited flexibility creates rents so that increasing flexibility raises costs in some Member States. Costs are reduced more by the CDM than by non-ETS trade. The CDM warrants market reduces costs by a small amount only; market power is a real issue. However, the warrants market is obsolete in case there is non-ETS trade. The CDM leads to price convergence between the ETS and non-ETS market. There would be one price for carbon in the European Union if the proposed limits on CDM access are relaxed slightly.

Key words: European Union, greenhouse gas emission reduction, clean development mechanism, permit trade

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1. Introduction

The European Union has announced ambitious greenhouse gas emission reduction targets for 2020, even if there is no wider international agreement on climate policy. In order to achieve this goal, the EU is creating a complex regulatory regime with differentiated targets, a range of policy instruments and restrictions on their application, and a variety of fungibilities between selected parts of the regulation. As a further complication, there are separate targets and instruments for renewable energy and energy efficiency; and emission reduction policy of course interacts with other arenas, including fiscal policy, industrial policy, and agricultural policy. To an outsider, the array of measures and initiatives is bewildering and clearly violates the simple prescriptions of textbook economics. As the European Commission has yet to publish a regulatory impact assessment, it is not clear to what extent the regulatory regime creates new distortions. Nor is it clear how far current policy is removed from the cost-effective policy.[1] Therefore, this paper seeks to analyze the regulatory regime – but because of the complexities, I focus on one specific part only: the market in warrants for certified emission reductions, and its interactions with the two primary markets for emission permits in the European Union.[2]

Certified emission reductions (CERs) are the reward for companies and governments that invest in the Clean Development Mechanism (CDM), the initiative through which rich

[1] Note that the EU targets are not efficient (Tol 2007;Tol 2008).

[2] Other papers focus on the artificial separation of emission reduction targets (Boehringer et al. 2006;Klepper & Peterson 2006), the interactions between abatement and other targets (Boehringer et al. 2008), the interactions between climate policy and other policies (Babiker et al. 2003;Dellink & van Ierland 2006;Fischer 2008;Palmer et al. 2007;Settle et al. 2007), the effect on climate policy on industrial competitiveness (Kuik & Gerlagh 2003), the functioning of the European Trading System (Benz & Trück 2009;Convery & Redmond 2007;Ellerman & Buchner 2007), and flexibility instruments for non-ETS emissions (Reilly et al. 2006;Tol 2009). There are also papers on flexibility in the renewables targets (Mundaca 2008;Oikonomou et al. 2008), and on linking EU permit markets to other permit markets (Anger 2008;Rehdanz & Tol 2005;Tol & Rehdanz 2008).

countries can finance emission abatement project in poor countries. The CDM is part of the Kyoto Protocol and thus due to expire in 2013, but something very similar is likely to be part of the international treaty that would succeed the Kyoto Protocol. If not, the EU would probably reach bilateral agreements with key countries that host CDM projects. In any case, the EU foresees a role for the CDM in its package of policies and measures to meet its targets for 2020. In fact, the EU expects that there will be an abundant supply of cheap CERs in 2020 – and in order to preserve "environmental integrity", has placed limits on the uptake of the CDM by EU Member States. Specifically, Member States may import only 3% of their 2005 emissions as CERs, although selected Member States may buy up to 4%.[3]

In the proposed regulation (CEC 2008b;EP 2008), the CDM quotas of EU Member States are tradable between countries. That is, the United Kingdom, say, may purchase the right to buy CERs from Poland, say – and the UK would if its marginal costs of emission reduction are higher than in Poland. The EU has thus created a market for CER warrants.[4] As with any emission permit market, this reduces the overall cost of meeting the target – but one should not forget that this market exists by virtue of artificial restrictions placed on the primary and secondary market. As with any market with a limited number of buyers and sellers (27 in this case), there may be issues of market power, rents, and reallocation of the burden of emission reduction. These issues are explored below.

Furthermore, the market for CER warrants interacts with the other markets for emission permits: the European Trading System that has been in place since 2005 and the newly created Member State exchange for non-ETS allocations (the so-called Swedish proposal). As CERs are not tied to either market, one would expect that the CDM would bring a degree of convergence between the ETS and non-ETS markets – and that the CER warrant market would bring further convergence. These issues are also addressed by the current paper.

[3] The implications of this restriction are straightforward. If emission reduction in a country is more expensive at the margin than the CER price, it should buy up to its limit. It is has yet to be investigated, however, how a national government should allocate its CDM quota to the companies in its jurisdiction.

[4] Note that there is already a market for the development of CDM projects, a secondary market on which the resulting CERs are traded, and a futures market for CERs.

In Section 2, I present an analytically tractable model of emission reduction and permit trade in the European Union. The model is calibrated to the impact assessment of the 2020 targets of the European Commission. The model is simple, but captures all the relevant features. In Section 3, I investigate the properties of the market for CDM warrants and its interaction with the regulations for ETS and non-ETS emissions. Section 4 concludes.

2. The model and its calibration

2.1. The primary markets

Let us consider a market for tradable emission reduction permits with *I* countries. Emission reduction costs *C* are quadratic. Without CDM, each country solves the problem:

(1a) $$\min_{R_i,P_i} C_i = \alpha_i R_i^2 Y_i + \pi P_i \text{ s.t. } R_i E_i + P_i \geq E_i - A_i$$

where *Y* is gross domestic product, indexed by *i*; *R* is relative emission reduction; *P* denotes the amount of emission permits bought or sold; *π* is the emission permit price (assuming a perfect market, all companies face the same price, so there is no index); *E* are the emissions without emission reduction, so that *E*(1-*R*)+*P* are the emissions with emission reduction; *A* are the allocated emission permits; that is, if a country emits more than has been allocated, *E*>*A*, it will have to reduce emissions or buy permits on the market; and *α* is a parameter. If a country's allocation exceeds its emissions, *E*<*A,* the optimization problem is:

(1b) $$\min_{R_j,P_j} C_j = \alpha_j R_j^2 Y_j - \pi R_j E_j + \pi P_j \text{ s.t. } P_j \geq E_j - A_j$$

We assume that the country sells its hot air *P*=*E*-*A*, and in addition reduces emissions by *RE* which it sells at the market for *πRE*. Countries with hot air are indexed by *j*. Countries without emission reduction targets are excluded from the market, that is CDM and similar instruments are not considered.

The first order conditions of (1) are:

(2a) $$\begin{aligned} &2\alpha_i R_i Y_i - \lambda_i E_i = 0, i = 1,2,...,I \\ &2\alpha_j R_j Y_j - \pi E_j = 0, j = 1,2,...,J \end{aligned}$$

(2b) $$\pi - \lambda_i = 0, i = 1, 2, ..., I$$
$$\pi - \lambda_j = 0, j = 1, 2, ..., J$$

(2c) $$R_i E_i + P_i - E_i + A_i = 0, i = 1, 2, ..., I$$
$$P_j - E_j + A_j = 0, j = 1, 2, ..., J$$

where λ denotes the Lagrange multiplier. This is a system with 3(I+J) equations and 3(I+J)+1 unknowns, but we also have that aggregate supply must equal aggregate demand, that is

(2d) $$\sum_{i=1}^{I} P_i + \sum_{j=1}^{J} P_j - \sum_{j=1}^{J} R_j E_j = 0$$

which allows us to solve for the permit price π as well. (2) solves as:

(3a) $$\pi = \lambda_i = \frac{\sum_{i=1}^{I}(E_i - A_i) + \sum_{j=1}^{J}(E_j - A_j)}{\sum_{i=1}^{I} E_i^2 / 2\alpha_i Y_i + \sum_{j=1}^{J} E_j^2 / 2\alpha_j Y_j}$$

(3b) $$R_i = \frac{\pi E_i}{2\alpha_i Y_i}; R_j = \frac{\pi E_j}{2\alpha_j Y_j}$$

(3c) $$P_i = E_i - A_i - \frac{\pi E_i}{2\alpha_i Y_i} E_i; P_j = E_j - A_j$$

So, the permit price goes up if the emission reduction obligation increases or if the costs of emission reduction increase. All countries face the same marginal costs of emission reduction, and the trade-off between reducing emissions in-house and buying or selling permits is driven by the ratio of marginal emission reduction costs and the permit price. The modelled market behaves as expected.

We consider two cases. First, model (1-3) is applied separately to the emissions covered by the European Trading System and to the remaining emissions which are covered by the newly created Member State exchange for non-ETS emission allocation. Second, model (1-3) is applied to ETS emissions only. Note that the solution for non-ETS emissions without the market in emission permits (P_i=0) is trivial.

2.2. Certified emission reductions and the market in CDM warrants

The model in Section 2.1 was used to investigate the properties of the ETS and non-ETS markets (Tol 2009). That paper, however, omitted the Clean Development Mechanisms. This is added here.

Let us first consider the case without a CDM warrant market, and without trade in non-ETS emission allocations. There are three corner solutions. (1) The CER price is higher than the ETS price and higher than the marginal costs of non-ETS emission reduction. In this case, a Member State would not avail of its right to purchase CERs. (2) The non-ETS marginal cost is higher than the ETS price. In this case, a Member State would purchase CERs up to its 3% or 4% limit and use the CERs to lower its non-ETS emission reduction obligation. (3) The non-ETS marginal cost is lower than the ETS price. In this case, a Member State would purchase CERs up to its 3% or 4% limit and use the CERs to lower its ETS emission reduction obligation, thus reducing the ETS price for all other Member States as well. Besides the corner solutions, there may be an interior solution that mixes two or three of the above cases. Although the 3% limit on the use of CERs seems strict, the results below reveal that interior solutions are in fact quite common.

Let us now consider a market in CDM warrants. Again, there are three different corner solutions. (1) The CER price is higher than the ETS and the non-ETS price. No CERs would be bought. (2) The ETS price is higher than the non-ETS price; and the CER price is lower than the ETS price. Member States would purchase CERs up to their limit, and sell them on in the ETS market. There is no point in selling on the CDM warrant to another Member State as this would entail transaction costs but no gains. This can also be seen from Equation (3a) The ETS price is affected by the total emission allocation only – but not by the allocations to individual Member States. The ETS price determines the marginal abatement cost of all Member States, indeed equalizes them. This means that there no gains from reallocating CERs from one Member State to another. (3) The non-ETS price is higher. Member States would purchase CERs, and sell them on the non-ETS market. The warrant market is again defunct.

There may also be interior solutions, in which CERs are shared between ETS and non-ETS, or indeed not fully used. Also in this case, there is no need for a CDM warrant market through which ETS and non-ETS targets are re-allocated. The ETS and non-ETS markets are well able to do that.

That is, if there are markets for both ETS and non-ETS emission rights, there is no need for a market in CDM warrants. Rational actors would not trade at that market.

Note that the EU did create an ETS market, a non-ETS market, and a CDM warrant market. The warrant market is redundant. If all parties in all markets are aware of this, the warrant market is just a piece of unnecessary but otherwise innocent regulation. If not, confusion may be the result.

If there is no market for non-ETS permit, but there is a CDM warrant market, the following would happen. Let us assume that the ETS and CER prices are lower than the marginal abatement costs in the non-ETS sector in all Member States. Then, for a given supply of CERs, countries solve the problem:

(4) $$\min_{R_i,W_i} C_i = \alpha_i R_i^2 Y_i + \pi^C \left(D_i + W_i\right) + \pi^W W_i \text{ s.t. } R_i E_i + D_i + W_i \geq E_i - A_i, W_i \geq -D_i$$

where D is the maximum amount of CERs that can be used; W is the net amount of CDM warrants bought; π^C is the price of CERs; and π^W is the price of CDM warrants. To understand the notation, first consider W = 0. In this case, is π^W ineffective and the emission abatement obligation is reduced by D. If $W > 0$, country i buys more CERs and has to buy CDM warrants as well; but in return reduces less at home. If $W < 0$, country i buys fewer CERs, sells warrants, and reduces more at home. And, of course, the amount of CDM warrants sold cannot exceed the country's limit on CDM access D.

This has first order conditions:

(5a) $$2\alpha_i R_i Y_i - \lambda_i = 0$$

(5b) $$R_i E_i = E_i - A_i - D_i - W_i$$

(5c) $$W_i = -D_i$$

(5d) $$\pi^C + \pi^W - \lambda_i - \mu_i = 0$$

This solves as (5c) and

(6a) $$R_i = \left(E_i - A_i - D_i - D_i\right) / E_i$$

(6b) $$\lambda_i = 2\alpha_i Y_i \left(E_i - A_i - D_i - W_i\right) / E_i$$

(6c) $$\mu_i = \pi^C + \pi^D - 2\alpha_i Y_i \left(E_i - A_i - D_i - W_i\right) / E_i$$

Equation (6c) relates the shadow price of the availability of CERs to its constraint. The shadow price is the willingness to pay to release the constraint at the margin, so Equation (6c) is in fact an inverse demand function. Equation (6c) is linear, so it is obvious that it doubles as an inverse supply function for those countries that would sell their CDM warrants to other countries. The market clears where π^W is such that all μ_is are zero and the sum total of CERs is equal to total allowed use of the CDM.

If non-ETS marginal costs are higher than the ETS price in some countries, but lower in others,[5] there is an additional opportunity for arbitrage. Countries would supply a share of their CDM warrants to the non-ETS and use the remainder to buy CERs and sell them in the ETS – up to the point where the price of a CDM warrant equals the price difference between ETS and CDM. There need not be an interior solution to this, in which case all CERs go to either ETS or non-ETS.

2.3. Model calibration

The model is calibrated in four steps. The 2020 emission reduction targets are relative to 2005 emissions. We use two sets of data for total greenhouse gas emissions in 2005: the official country statistics as reported to the UNFCCC, and the emissions reported in impact assessment of the European Commission (Capros et al. 2008). See Table A1. There are substantial, unexplained differences between the data. The UNFCCC data allow for a reasonable approximation of the ETS share in the 2005 emissions.[6] See Table A2. The sector detail is much less for the European Commission data, and therefore I use an upper and lower bound of the ETS share, by putting all industry emissions and all non-energy CO2 emissions inside or outside the ETS. I refer to these calibrations as EUmax and EUmin. The European Commission study reports total emissions in 2005 and 2020 as well as growth rates for ETS and non-ETS emissions. Together, this implies ETS and

[5] Recall that there are countries with hot air. These countries would supply all their CDM warrants to other countries as long as the warrant price or the ETS is greater than the CER price.

[6] Note that the ETS / non-ETS split is an approximation because the UNFCCC statistics follow the sectoral classification of the International Energy Agency, while the ETS is based on installations. For instance, the power plant of a large university would be classified as “institutional” in the UNFCCC – and would thus be placed outside the ETS even though it is in reality covered.

non-ETS emissions in 2005 and 2020.[7] This results in negative emissions for Denmark and Luxembourg, so I replaced the ETS share for these countries with average of the upper and lower bound. I refer to this calibration as EUmid.[8] Note that EUmid does not necessarily lie in between EUmax and EUmin (see Table A2), which suggests that there are further problems with the data of Capros *et al*. (2008).

For 2020, I use four alternative emissions projections, viz. (1) the UNFCCC data for 2005 with the ETS and non-ETS growth rates of (Capros, Mantzos, Papandreou, & Tasios 2008); (2) the EU data for 2005 and 2020 with lower bound ETS; (3) the EU data with upper bound ETS; and (4) the EU data as calibrated above. See Table A1 for the total emissions, and Table A2 for the ETS share.

I use a single projection (Capros, Mantzos, Papandreou, & Tasios 2008) for population and Gross Domestic Product. In Western Europe, the population grows by 0.25% per year between 2005 and 2020 and the economy by 2.09%, so that GDP per capita increases by 1.84%. Southern Europe grows slightly faster, with a population growth of 0.26% and an economic growth of 2.29% per year. GDP per capita in Southern Europe thus grows at 2.03%. Southern Europe catches up with Western Europe, but only slowly. The average GDP/capita in Western Europe in 2020 is projected to be €39,170 compared on €29,702 in Southern Europe. In Eastern Europe, population is assumed to fall by 0.32% per year while the economy grows by 4.51% per year. GDP/capita grows by 4.85% per year to €12,656 in 2020.

For each of the four emissions baselines, I calibrate the unit cost parameters α_i for emission reduction in the ETS by assuming that these are proportional to the square root of the relative carbon efficiency of the economy (Rehdanz et al. 2006), as follows:

(5) $$\alpha_i \propto 1.57 - 0.17\sqrt{\frac{E_i}{Y_i} - \min_i \frac{E_i}{Y_i}}$$

Furthermore, I assume that π=€40/tCO_2 in 2020 (Capros, Mantzos, Papandreou, & Tasios 2008). See Table A3.

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[7] We know that $E_{2005} + N_{2005} = M_{2005}$, where E_{2005} are ETS emissions in 2005, N are non-ETS emissions and M are total emissions. We also know that $E_{2020} + N_{2020} = E_{2005}(1+g_E)^{15} + N_{2005}(1+g_M)^{15} = M_{2020}$ where g_E is the annual growth rate of ETS emissions, and g_M of non-ETS emissions. Capros *et al*. (2008) report M_{2005}, M_{2020}, g_E and g_M, so that we have two equations and two unknowns (E_{2005}, N_{2005}).

[8] The UNFCCC values for Cyprus and Malta are set equal to their EUmid values.

The unit cost parameters α_i for non-ETS emissions are set such that the cost-effective non-ETS emission reduction targets of (Capros, Mantzos, Papandreou, & Tasios 2008) are cost-effective in this model as well. See Table A4. For EUmid, there is a variant: I calibrate the unit cost parameters such that the marginal cost is as reported in the impact assessment of the European Commission (CEC 2008a;CEC 2008b).[9] I refer to this scenario as EUprice.

3. Scenarios and results

3.1. Policy scenarios

I distinguish seven different policy cases. See Table 1. In all cases, there is trade in emission permits in the EU Emission Trading Scheme. In the first case, the ETS is the only flexibility instrument. In the second case, I add the non-tradable 1% access to CDM for selected countries, and let Member States chose whether to loosen ETS or non-ETS targets. In the third case, I add the 3% access to CDM, and let Member States freely allocate this to either the ETS or the non-ETS sector. In the fourth case, there is trade in CDM warrants between those countries that have allocated their CERs to their non-ETS emissions. In the fifth case, there is no CDM, but there is a market for non-ETS emission permits. In the sixth case, I reintroduce the 1% CDM for selected countries; and in the seventh case, I add the 3% CDM.

3.2. EU-wide results

Table 2 shows the first set of results, focusing on the total economic cost to the EU in 2020. In the central model calibration (EUmid), the economic cost amounts to 1.3% of GDP if the ETS is the only flexible instrument. The costs drop to 0.9% of GDP if the CDM is used to its maximum amount of 3% or 4% of 2005 emissions. A market for CDM warrants further reduces costs, but only marginally. 66% percent of CERs are used to offset ETS emissions, the remaining 34% is used in the non-ETS sector.

[9] Note that there are four countries with hot air. I keep the unit cost parameters as in the EUmid scenario. For Portugal, I reduced the baseline non-ETS emissions to the target.

The impact of the CDM, however limited in size, is impressive compared to the impact of the Swedish proposal which introduces trade in non-ETS emission allotments. The Swedish proposal reduces costs to 1.2% of GDP only. Of course, costs are lowest (0.7% of GDP) if the CDM and Swedish proposal are combined. In this case, all CERs are used in the ETS market.

Table 3 shows the permit price. With the ETS only, the permit price is calibrated to be €40/tCO_2. This falls to €35/tCO_2 with CDM access, and to €30/tCO_2 with both CDM and non-ETS trade – the latter result holds because trade in non-ETS allotments takes the pressure of that sector and releases CERs to the ETS. CDM warrants would trade at €23/tCO_2 – that is, Member States are prepared to pay €23/tCO_2 for the right to buy a CER at the assumed price of €10/tCO_2/tCO_2. The ETS price is €33/tCO_2 in this case. In the non-ETS sector, the permit price is €27. This is always below the ETS price, so no CDM is deployed to offset non-ETS emissions (cf. Table 2). Table 3 also shows that if the CDM limit is raised from 3.0% to 3.8%, the ETS and non-ETS price are equal, that is, the emissions target is met at the lowest possible cost. The permit price is then €27/tCO_2.

The above results hold for one particular interpretation of the base year (2005), the no policy scenario, and the marginal abatement cost curve. Tables 2 and 3 also show results for the four alternative calibrations outlined in the previous section. The qualitative pattern in Table 2 is identical: More flexibility means lower costs, and the CDM is more effective at lowering costs than the Swedish proposal. Table 3 confirms this, but finds that the ETS price converges to the non-ETS price! In fact, if all CERs were allocated to the ETS, the ETS price would fall below the non-ETS price. That would be irrational, so CERs are shared between the two markets. Table 2 shows that less than one-third of the CERs is allocated to the non-ETS sector in the EUmin calibration, and less than one-twentieth in the other three calibrations. That is, the interaction between the three markets is such they in fact function as a single market.

In each of the five alternative model calibrations, the non-ETS permit price is below the ETS permit price. The reason is the overallocation of non-ETS permits to countries in Eastern and Southern Europe. In order to test the sensitivity of the results to this, Tables 2 and 3 show the results of higher projected emissions and higher non-ETS abatement costs, in both cases taking the EUmid calibration for 2005. Not surprisingly, emission reduction costs are higher. The qualitative pattern in Table 2 does not change, however. More flexibility means lower costs, and CDM access is more important than non-ETS trade. Table 3 reveals that the price of CDM warrants is well above the price of ETS permits. Consequently, all CERs are used in the non-ETS sector. For the same reason, the trade in rights to purchase CERs has a bigger effect. For instance, in the high cost case, total abatement costs are reduced from 1.4% of GDP to 1.3% of GDP. Under the Swedish proposal, CDM access reduces the marginal cost of non-ETS abatement, but the permit price stays above the ETS permit price. CDM access would have to rise from 3.0% of 2005 emissions to 3.7% (high cost case) or even 6.5% (high emissions case) for the market prices to equilibrate.

Finally, Tables 2 and 3 show what happens if the price of CERs is not €10/tCO_2 but rather €5/tCO_2 or €15/tCO_2. The impact is minimal. Overall costs fall or rise with a higher CER price, but the effect is not very large. ETS and non-ETS permit prices are hardly affected as they are still much higher than the CER price. The only substantial impact is on the price of CDM warrants: The higher (lower) the CER price, the lower (higher) the warrant price, almost one-to-one with the CER price. The effect on abatement is muted, however, kept in check by market forces and alternative options to abate emissions. In the base case (€10/tCO_2), 66.09% of CERs are used to offset ETS emissions. With a low CER price (€5/tCO_2), this rises to 66.11%; with a high CER price (€15/tCO_2) this falls to 65.96%.

3.3. Results per Member State

Table 4 shows the total cost of emission abatement for each of the 27 Member States in the 7 policy cases, for the EUmid calibration and for costs, projections, and CER price as in the central case.

There is substantial variation in costs between the Member States if the ETS is the only flexibility mechanism. The EU average of 1.3% of GDP hides gains of 10.1% for Bulgaria and losses of 5.1% for Latvia. Increasing flexibility reduces the overall costs to the EU and to most of the Member States. However, Latvia faces the highest costs in all policy scenarios, and its costs fall by less than the average as flexibility increases. This is because its marginal abatement cost curve is shallower than any other Member State, so that it cannot compete at the margin. Cyprus and Poland turn from net losers to net winners as flexibility increases, and the Czech Republic similar sees more export opportunities with increasing flexibility. On the other hand, Bulgaria, Estonia (non-ETS only), and Malta are outcompeted and see their gains of permit trade fall as flexibility increases. This implies that increased flexibility is not Pareto superior. The current regulation (ETS only) creates scarcity rents that some Member States would prefer to keep.

Table 5 shows the total allocation of CERs, and the CERs used to offset non-ETS emissions in case the ETS is the only flexibility mechanism. Without a market for CDM warrants, the pattern of ETS/non-ETS allocation essentially follows the marginal abatement costs. Countries with high (low) non-ETS abatement costs allocate all (none) of their CERs to the non-ETS sectors. For some countries, the marginal abatement costs in the non-ETS are sufficiently close to the ETS price. These countries allocate part of their CERs to the non-ETS sector, and the remainder to the ETS.

With a market for CDM warrants, the allocation changes for two reasons. First, prices and marginal costs change. This leads to a reallocation between ETS and non-ETS independent of trade per se. Belgium is an example. Second, some countries reallocate part of their CERs to the non-ETS sector for the sole purpose of selling them on to other Member States. Poland is an example.

Table 5 also shows the market shares at the market for CDM warrants. The market is concentrated both at the demand and the supply side. At the supply side, the HHI is 1665, usually a reason for concern. Poland is the biggest seller, with almost one-third of the market. The Czech Republic, Greece and Romania each have more than 10% of the market. At the demand side, concentration is even higher with a HHI of 3924. Denmark buys 58% of all warrants, Luxemburg 21% and Sweden 11%.

4. Discussion and conclusion

The European Union (EU) plans to introduce four kinds of flexibility in the regulation of greenhouse gas emissions for the period 2013-2020: (1) the emissions trading scheme (ETS), a permit market for companies in selected sectors; (2) trade between Member State in non-ETS emission reduction obligations; (3) investments in (the successor to) the

Clean Development Mechanism (CDM) to reduce emissions outside the EU; and (4) trade between Member States in CDM warrants. This paper considers the interactions between these four markets.

The key findings are as follows. Greater flexibility reduces overall costs. However, limited flexibility creates rents for certain Member States, which consequently may oppose increased flexibility. Access to the CDM is more effective at reducing costs than is non-ETS trade. The market in CDM warrants is small, concentrated, and relatively ineffective in case there is no trade in non-ETS allotments. If there is non-ETS trade, the CDM warrant market is superfluous. These results are robust to the calibration of the model and to the projections of future emissions. The prices of carbon in the ETS and the non-ETS sector converge due to access to the CDM. In some calibrations, convergence is compete for the proposed access limit to the CDM while in other calibrations a relatively modest extension of the limit would imply that there is a single price for greenhouse gas emissions across Member States and sectors.

The above results come with a number of caveats. The results are based on a simple model. More elaborate models would be harder to solve without adding much insight – unless, of course, interactions and complications are introduced that are omitted from the current analysis. Chief among these are EU energy policy; intra-union trade in goods and services; and interactions with fiscal, energy and agricultural policy. The current paper tacitly assumes that permit markets are perfect. I do find signs of market power for the trade of CDM warrants – but that market is obsolete. The non-ETS market may be imperfect too. The current paper also omits any discussion of how markets could and should be designed. I simply assumed that there will be functioning markets. The proposed regulations are complicated, and this increases the administrative burden of companies and regulators alike. The proposed regulations also have a number of ambiguities, the most important of which is the creation of an obsolete market. These issues will be ironed out, but they do increase regulatory uncertainty in the interim. All of these issues are deferred to future research.

Subject to these caveats, however, the bottom-line conclusion of this paper is that the European Union created, in a roundabout way and with unnecessary administrative costs and regulatory uncertainty, a set of regulations for greenhouse gas emission abatement that is close to cost-effective or perhaps even cost-effective.

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Table 1. Policy scenarios

	Case[a]	ETS	non-ETS	CDM	WM
1	ETS	Yes	No	0%	n/a
2	ETS+1	Yes	No	1%	n/a
3	ETS+1+3	Yes	No	1%+3%	No
4	ETS+1+3+WM	Yes	No	1%+3%	Yes
5	ETS+SP	Yes	Yes	0%	n/a
6	ETS+SP+1	Yes	Yes	1%	n/a
7	ETS+SP+1+3	Yes	Yes	1%+3%	n/a

[a] ETS: Emission trading scheme; 1: 1% CDM for selected countries; 3: 3% CDM for all countries; WM: warrant market; SP: Swedish proposal

Table 2. The total cost (in %GDP of the EU27 in 2020) of meeting the emission targets for seven different policy cases (columns) and nine different model calibration (rows). The right-most column has share of CERs allocated to the ETS in the case of the Swedish proposal with 1+3% CDM.

Case	1	2	3	4	4	5	6	7	7
CDM	0	1	1+3	1+3	Share CER in ETS	0	1	1+3	Share CER in ETS
WM	No	No	No	Yes		No	No	No	
SP	No	No	No	No		Yes	Yes	Yes	
EUmid	1.313	1.273	0.995	0.994	66%	1.159	1.130	0.774	100%
EUmin	1.215	1.176	0.899	0.896	40%	1.044	1.013	0.685	71%
EUmax	1.364	1.325	1.045	1.044	59%	1.218	1.187	0.835	96%
EUprice	1.484	1.419	1.083	1.053	40%	1.192	1.169	0.807	97%
UN	1.204	1.167	0.888	0.887	58%	1.043	1.015	0.680	97%
High emit	2.694	2.642	2.051	1.972	0%	2.271	2.228	1.878	100%
High cost	2.219	2.103	1.406	1.302	0%	1.747	1.673	1.174	100%
High CDM	1.313	1.276	1.048	1.047	66%	1.159	1.133	0.774	100%
Low CDM	1.313	1.270	0.942	0.942	66%	1.159	1.127	0.774	100%

Table 3. The price of emission permits (in €/tCO_2) in the ETS, the warrant market for CDM, and the non-ETS, for nine alternative model calibrations and seven policy cases (cf. Table 1). The second-right-most column shows the limit to the CDM for which ETS and non-ETS equilibrate, and the right-most column the price at which the two markets equilibrate.

	ETS price					WM	Non-ETS price			CDM	
Case	1	2	3	7	4	4	5	6	7	7	7
CDM	0	1	1+3	1+3	1+3	1+3	0	1	1+3	%	€/tCO_2
SP	No	No	No	Yes	No	No	Yes	Yes	Yes	Yes	Yes
ARM	No	No	No	No	Yes	No	No	No	No	No	No
Mid	40.0	39.6	33.2	29.9	33.3	33.3	27.4	27.4	27.4	3.8	27.4
Min	40.0	39.3	32.5	27.9	33.2	33.2	30.8	30.3	27.9	3.0	27.9
Max	40.0	39.5	33.8	30.1	33.9	33.9	30.7	30.0	30.1	3.0	30.1
Price	40.0	39.9	33.8	30.2	35.9	35.9	30.7	29.3	30.2	3.0	30.2
UN	40.0	39.5	33.1	28.7	33.2	33.2	29.3	28.7	28.7	3.0	28.7
High emit	40.0	40.0	38.0	29.9	40.0	53.2	50.8	49.8	40.6	6.5	29.9
High cost	40.0	39.9	36.9	29.9	39.9	64.1	83.9	79.8	39.5	3.7	29.9
High CDM	40.0	39.6	33.2	29.9	33.3	33.3	27.4	27.4	27.4	3.8	27.4
Low CDM	40.0	39.6	33.2	29.9	33.3	33.3	27.4	27.4	27.4	3.8	27.4

Table 4. The total cost (in %GDP in 2020) per Member State of meeting the emission targets for seven different policy cases (cf. Table 1).

Case	1	2	3	4	5	6	7
CDM	0	1	1+3	1+3	0	1	1+3
WM	No	No	No	Yes	No	No	No
SP	No	No	No	No	Yes	Yes	Yes
Austria	1.816	1.719	1.381	1.383	1.738	1.674	1.208
Belgium	1.983	1.840	1.506	1.507	1.954	1.805	1.345
Bulgaria	-10.106	-9.771	-6.435	-6.497	-13.439	-12.999	-8.207
Cyprus	0.362	0.218	0.011	0.012	0.354	0.213	-0.050
Czechia	-1.123	-1.078	-1.079	-1.089	-2.140	-2.049	-2.021
Denmark	1.463	1.309	0.904	0.870	1.059	1.005	0.684
Estonia	0.523	0.584	0.737	0.726	-0.128	-0.025	0.178
Finland	1.544	1.416	1.102	1.103	1.523	1.393	0.963
France	0.642	0.641	0.459	0.459	0.603	0.596	0.374
Germany	0.972	0.977	0.779	0.778	0.953	0.957	0.695
Greece	1.012	1.012	0.673	0.672	0.964	0.973	0.508
Hungary	1.772	1.785	1.510	1.508	1.351	1.391	0.976
Ireland	2.127	2.004	1.577	1.580	1.931	1.865	1.335
Italy	2.300	2.189	1.790	1.793	2.193	2.123	1.549
Latvia	5.082	5.049	4.306	4.314	4.990	4.975	3.852
Lithuania	2.044	2.028	1.494	1.497	1.336	1.367	0.565
Luxembourg	1.989	1.885	1.560	1.529	1.699	1.628	1.282
Malta	-3.103	-3.064	-2.849	-2.858	-3.240	-3.188	-2.800
Netherlands	2.376	2.364	1.892	1.895	2.268	2.246	1.657
Poland	1.608	1.613	1.080	1.079	0.256	0.333	-0.462
Portugal	2.084	1.913	1.485	1.486	1.872	1.714	1.091
Romania	2.336	2.376	2.228	2.222	1.143	1.258	0.972
Slovakia	2.251	2.271	2.001	1.998	1.600	1.659	1.233
Slovenia	1.862	1.857	1.448	1.449	1.811	1.817	1.240
Spain	1.418	1.287	1.017	1.017	1.376	1.236	0.887
Sweden	1.822	1.752	1.433	1.435	1.722	1.675	1.241
UK	1.012	1.011	0.716	0.717	0.917	0.913	0.612
EU	*1.313*	*1.273*	*0.995*	*0.994*	*1.159*	*1.130*	*0.774*

Table 5. The total (1%+3%) allocation of CERs (in million metric tonne of carbon dioxide per year) per Member State, the allocation to the non-ETS sector (without non-ETS trade) with and without a CDM warrant market, the net purchase of CDM warrants, and the total allocation of CERs to the non-ETS sector after trade. The rightmost column gives the market share on the CDM warrants market, where negatives denote net sellers and positive net buyers.

	Total	Non-ETS		Net purchase	Total WM	Market share
		No WM	WM			
Case	3, 4, 7	3	4	4	4	4
Austria	3.9	2.1	2.1	0.0	2.1	0.1%
Belgium	5.7	0.9	2.3	0.0	2.3	0.1%
Bulgaria	2.0	0.0	0.1	-0.1	0.0	-5.6%
Cyprus	0.3	0.0	0.1	0.0	0.1	-0.4%
Czechia	4.4	0.0	0.3	-0.3	0.0	-12.5%
Denmark	2.6	2.6	2.6	1.3	4.0	57.6%
Estonia	0.6	0.0	0.0	0.0	0.0	-1.6%
Finland	2.8	0.4	1.1	0.0	1.1	0.0%
France	16.8	7.9	7.7	0.0	7.7	0.7%
Germany	30.1	4.5	4.5	0.0	4.5	0.2%
Greece	4.0	0.0	0.3	-0.3	0.0	-11.4%
Hungary	2.4	0.0	0.2	-0.2	0.0	-6.8%
Ireland	3.0	3.0	3.0	0.2	3.2	7.9%
Italy	23.0	15.1	14.9	0.0	15.0	0.5%
Latvia	0.3	0.0	0.0	0.0	0.0	-0.9%
Lithuania	0.6	0.0	0.0	0.0	0.0	-1.7%
Luxembourg	0.6	0.6	0.6	0.5	1.0	20.5%
Malta	0.1	0.0	0.0	0.0	0.0	-0.3%
Netherlands	6.6	5.5	5.4	0.0	5.4	0.1%
Poland	11.2	0.0	0.8	-0.8	0.0	-32.2%
Portugal	3.5	0.0	1.0	-0.2	0.9	-7.5%
Romania	4.5	0.0	0.3	-0.3	0.0	-12.9%
Slovakia	1.5	0.0	0.1	-0.1	0.0	-4.4%
Slovenia	0.6	0.0	0.0	0.0	0.0	-1.7%
Spain	18.0	3.4	7.7	0.0	7.7	1.1%
Sweden	2.8	2.8	2.8	0.3	3.1	11.1%
UK	21.1	8.2	8.2	0.0	8.2	0.1%
EU	*172.9*	*57.0*	*66.2*	*0.0*	*66.2*	

Table A1. Greenhouse gas emissions (million metric tonne of carbon dioxide equivalent) in 2005 and 2020, and the average annual growth rate.

	EU			UNFCCC		
	2005	2020	growth	2005	2020	Growth
Austria	97.9	104.2	0.42	93.5	98.6	0.35
Belgium	141.4	152.5	0.51	142.3	151.3	0.41
Bulgaria	65.2	68.4	0.32	70.5	73.3	0.26
Cyprus	8.6	8.5	-0.08	8.6	8.4	-0.16
Czechia	145.4	143.0	-0.11	145.9	143.8	-0.09
Denmark	66.0	64.5	-0.16	63.6	62.1	-0.16
Estonia	18.9	21.7	0.93	19.3	22.2	0.94
Finland	69.1	70.6	0.14	69.1	70.1	0.10
France	561.0	555.7	-0.06	562.9	550.5	-0.15
Germany	1003.3	999.4	-0.03	1005.4	984.3	-0.14
Greece	131.8	136.6	0.24	133.8	136.8	0.14
Hungary	78.9	90.8	0.94	80.2	91.9	0.91
Ireland	75.8	80.7	0.42	70.4	75.2	0.44
Italy	575.7	644.6	0.76	462.9	513.0	0.69
Latvia	10.8	17.8	3.39	11.0	17.8	3.28
Lithuania	19.3	23.5	1.32	13.3	16.3	1.37
Luxembourg	13.9	15.1	0.55	22.7	24.6	0.55
Malta	3.5	2.8	-1.48	3.5	3.0	-1.01
Netherlands	220.8	241.5	0.60	211.8	230.0	0.55
Poland	373.6	423.1	0.83	388.7	439.6	0.82
Portugal	87.3	97.3	0.73	87.5	96.6	0.67
Romania	149.4	189.8	1.61	152.0	192.6	1.59
Slovakia	50.5	60.7	1.23	49.4	58.9	1.18
Slovenia	19.7	23.2	1.10	20.5	24.0	1.06
Spain	449.6	491.8	0.60	441.1	474.8	0.49
Sweden	70.0	82.6	1.11	67.0	78.0	1.02
UK	703.8	684.3	-0.19	658.8	622.0	-0.38
EU27	5211.2	5494.6	0.35	5055.6	5259.6	0.26

Table A2. The share of ETS in total emissions (cf. Table A1) in four alternative calibrations.

	EUmin		EUmid*		EUmax		UNFCCC	
	2005	2020	2005	2020	2005	2020	2005	2020
Austria	0.20	0.22	0.49	0.51	0.47	0.48	0.33	0.35
Belgium	0.18	0.22	0.55	0.57	0.41	0.42	0.34	0.36
Bulgaria	0.43	0.43	0.67	0.70	0.61	0.63	0.60	0.63
Cyprus	0.41	0.34	0.36	0.31	0.47	0.41	0.42	0.37
Czechia	0.44	0.39	0.51	0.47	0.66	0.62	0.49	0.46
Denmark	0.34	0.33	0.40	0.40	0.46	0.45	0.46	0.46
Estonia	0.60	0.57	0.58	0.58	0.68	0.69	0.80	0.80
Finland	0.33	0.39	0.56	0.59	0.56	0.58	0.52	0.55
France	0.11	0.09	0.13	0.11	0.29	0.27	0.24	0.22
Germany	0.35	0.37	0.73	0.75	0.53	0.54	0.43	0.44
Greece	0.38	0.36	0.42	0.40	0.51	0.49	0.60	0.58
Hungary	0.24	0.25	0.60	0.61	0.36	0.37	0.39	0.40
Ireland	0.20	0.22	0.39	0.44	0.33	0.37	0.41	0.46
Italy	0.27	0.28	0.51	0.53	0.47	0.48	0.38	0.40
Latvia	0.20	0.20	0.43	0.47	0.31	0.37	0.32	0.35
Lithuania	0.31	0.32	0.33	0.34	0.38	0.40	0.44	0.45
Luxembourg	0.09	0.09	0.17	0.16	0.24	0.24	0.18	0.17
Malta	0.54	0.32	0.52	0.33	0.54	0.32	0.42	0.25
Netherlands	0.30	0.34	0.45	0.50	0.46	0.50	0.42	0.47
Poland	0.46	0.44	0.36	0.36	0.58	0.58	0.60	0.60
Portugal	0.31	0.34	0.50	0.54	0.47	0.50	0.44	0.49
Romania	0.30	0.30	0.51	0.52	0.54	0.57	0.47	0.48
Slovakia	0.31	0.30	0.55	0.57	0.59	0.61	0.46	0.48
Slovenia	0.31	0.28	0.42	0.38	0.48	0.44	0.46	0.42
Spain	0.28	0.25	0.19	0.18	0.50	0.48	0.43	0.42
Sweden	0.11	0.11	0.35	0.41	0.38	0.45	0.30	0.35
UK	0.32	0.33	0.70	0.72	0.46	0.47	0.40	0.43
EU27	0.30	0.30	0.49	0.50	0.48	0.48	0.42	0.43

* The EUprice scenario uses the same projections as EUmid.

Table A3. Unit cost parameters in ETS according to five alternative calibrations; the EU27 is the weighted average, using baseline emissions as weights; the last two columns show the mean and standard deviation.

	EUmin	EUmid	EUmax	EUprice	UNFCCC	mean	st.dev.
Austria	13.8	19.8	19.6	19.8	19.1	18.4	2.6
Belgium	13.8	19.6	19.6	19.6	19.0	18.3	2.6
Bulgaria	13.0	18.4	18.3	18.4	17.6	17.1	2.3
Cyprus	13.6	19.9	19.6	19.9	19.0	18.4	2.7
Czechia	13.3	19.2	18.8	19.2	18.4	17.8	2.5
Denmark	13.8	20.0	19.8	20.0	19.1	18.5	2.7
Estonia	13.0	19.0	18.6	19.0	17.8	17.5	2.5
Finland	13.6	19.7	19.5	19.7	18.8	18.3	2.6
France	14.1	20.6	20.2	20.6	19.6	19.0	2.8
Germany	13.6	19.5	19.5	19.5	18.9	18.2	2.6
Greece	13.5	19.7	19.3	19.7	18.6	18.2	2.6
Hungary	13.6	19.3	19.4	19.3	18.6	18.0	2.5
Ireland	13.8	19.9	19.8	19.9	19.0	18.5	2.6
Italy	13.7	19.7	19.5	19.7	19.1	18.3	2.6
Latvia	13.7	19.5	19.4	19.5	18.8	18.2	2.5
Lithuania	13.5	19.7	19.4	19.7	18.9	18.2	2.6
Luxembourg	14.0	20.2	20.0	20.2	19.2	18.7	2.7
Malta	13.6	19.9	19.7	19.9	19.1	18.4	2.7
Netherlands	13.7	19.7	19.5	19.7	18.9	18.3	2.6
Poland	13.2	19.4	18.8	19.4	18.1	17.8	2.6
Portugal	13.6	19.5	19.3	19.5	18.7	18.1	2.6
Romania	13.3	19.0	18.7	19.0	18.1	17.6	2.4
Slovakia	13.4	19.1	18.8	19.1	18.4	17.8	2.5
Slovenia	13.6	19.6	19.3	19.6	18.7	18.2	2.6
Spain	13.7	20.2	19.5	20.2	18.9	18.5	2.7
Sweden	14.1	20.1	19.9	20.1	19.3	18.7	2.6
UK	13.7	19.7	19.7	19.7	19.1	18.4	2.6
EU27	13.6	19.6	19.4	19.6	18.8	18.2	2.6

Table A4. Unit cost parameters in non-ETS according to five alternative calibrations; the EU27 is the weighted average, using baseline emissions as weights; the last two columns show the mean and standard deviation.

	EUmin	EUmid	EUmax	EUprice	UNFCCC	mean	st.dev.
Austria	26.6	17.6	17.4	25.6	22.0	21.8	4.3
Belgium	30.4	16.0	20.1	18.6	23.6	21.7	5.6
Bulgaria	81.0	65.6	70.8	65.6*	87.4	74.1	9.7
Cyprus	23.4	28.2	21.7	37.0	25.5	27.2	6.0
Czechia	58.0	51.0	33.4	51.0*	52.9	49.3	9.3
Denmark	26.7	29.9	21.0	31.1	25.7	26.9	4.0
Estonia	24.9	30.2	23.2	29.0	14.9	24.4	6.1
Finland	36.2	24.5	18.6	12.8	26.7	23.7	8.8
France	25.4	26.4	20.5	26.1	22.9	24.2	2.5
Germany	38.9	17.7	24.5	10.9	38.1	26.0	12.4
Greece	29.2	27.3	22.4	37.8	19.1	27.2	7.2
Hungary	34.3	18.3	28.8	20.2	28.2	25.9	6.6
Ireland	23.5	23.5	24.0	24.5	21.3	23.4	1.2
Italy	26.9	19.1	19.4	39.0	19.5	24.8	8.6
Latvia	17.3	12.4	14.9	43.4	15.0	20.6	12.9
Lithuania	22.5	22.2	20.9	15.0	12.8	18.7	4.5
Luxembourg	23.7	22.0	19.1	40.6	35.4	28.2	9.3
Malta	21.4	26.8	21.4	47.5	32.1	29.8	10.8
Netherlands	28.7	26.0	22.9	26.0	26.5	26.0	2.1
Poland	37.5	48.7	32.5	48.7*	31.7	39.8	8.4
Portugal	34.6	29.8	29.5	29.8*	33.0	31.3	2.3
Romania	38.7	28.3	26.5	30.2	30.9	30.9	4.7
Slovakia	38.3	27.4	25.8	24.1	32.0	29.5	5.7
Slovenia	24.9	21.0	18.7	62.8	20.3	29.5	18.7
Spain	21.7	26.7	15.7	55.3	18.3	27.6	16.1
Sweden	12.8	11.7	11.9	22.1	12.2	14.2	4.5
UK	38.7	41.3	36.8	9.8	76.6	40.7	23.8
EU27	32.4	28.2	24.8	32.0	34.7	30.4	3.9

* As in EUmid.

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