The 2018 reform of EU ETS: consequences for project appraisal

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ABSTRACT
The European Union’s Emissions Trading System used to be a cap-and-trade scheme with a fixed supply of permits. However, a recent reform of the system ‘punctures the waterbed’ by making the supply of permits endogenous.

The current paper discusses how to handle permits in economic evaluations such as cost–benefit analysis. It derives general equilibrium rules for schemes with a fixed cap as well as schemes with an endogenous cap.

The paper also derives a cost–benefit rule to use when an exogenous reduction in emissions causes an induced intertemporal change in the supply of permits, what is termed a (positive or negative) permit multiplier, under an endogenous cap. For example, an induced reduction in emissions is associated with climate-related benefits but comes at a cost as production is displaced when the number of available permits decreases. The permit multiplier implies that emissions within the EU ETS are valued differently from emissions occurring elsewhere even under an endogenous cap.

A further novel result is that an endogenous cap could increase the social profitability of abatement efforts. By replacing purchases of permits, abatement could cause a reduction in the endogenous supply of permits and hence emissions.

1. Introduction

It is well-known that the costs of reducing greenhouse gas emissions may be lowered by allowing (international) trade in emission rights. The European Union’s Emissions Trading System (EU ETS) is the most important attempt to bring in the benefits from trade in greenhouse emission permits, accounting for over three quarters of international carbon trading. The EU ETS covers the energy sector, energy-intensive industrial emitters, and commercial aviation, representing about 45 per cent of total greenhouse gas emissions in the European Economic Area, EEA, that is, the EU plus Iceland, Liechtenstein, and Norway.

A firm emitting greenhouse gases is required to possess a permit for each and every ton of greenhouse gases (CO₂ equivalents) it emits. Some permits are auctioned others provided free of charge (known as grandfathering). An important reason for grandfathering is to protect industries that are at risk of leaving the union if costs become too high. Whether permits are purchased or received free of charge has important distributional consequences, but the efficiency properties of the system are not affected, at least not according to typical textbook presentations; refer to Johansson and
Kriström (2016, 2018). Total emissions remain unaffected by the way permits are allocated in a fixed cap-and-trade system.

Critics of the EU ETS have focused on the ‘oversupply’ of permits, claiming that the resulting low permit price delays transformation to production based on renewable resources. For some years, the permit price hovered around EUR 5–6 for a permit. Therefore, the system was reformed in 2018. From 2019 the issuance of new permits is adjusted by the Market Stability Reserve (MSR). Twenty-four per cent of the total surplus of permits, known as the Total Number of Allowances in Circulation (TNAC), is withheld from the yearly auctions and transferred to the MSR if the surplus is at least 833 million permits, which is around 60 per cent of the current surplus. This fraction is reduced to 12 per cent from 2024. The rules for the MSR also stipulate that 100 million permits (or the entire remaining reserve if this is smaller than 100 million permits) must be released from the reserve and auctioned whenever the surplus falls short of 400 million permits. From 2023 there will be a cap on the number of permits that can be held in the MSR. Permits above the cap will be automatically and permanently annulled. The cap will equal the number of permits that was auctioned during the previous year (by regulation, auctioned permits amount to 57 per cent of all issued permits).

In 2020 (up to late September) the permit price has hovered around EUR 20-30. One reason for this price hike is probably that the supply of permits now is endogenous, at least over the next few years. This means that if a country reduces its emissions by one ton, it could cause a reduction in total emissions. In contrast, in the pre-reform configuration, emissions were simply reshuffled because the supply of permits was exogenous. The reform is said to ‘puncture the waterbed’. Unfortunately, the new configuration is difficult to fully see through, leading to quite different predictions by different economists. Some, like Rosendahl (2019a, 2019b) claim that reducing emissions in a country may actually cause total EU ETS emissions to increase, what Sinn (2008) termed a Green Paradox, while others, like Perino (2018) and Silbye and Sørensen (2019) find that the reform punctures the waterbed, that is, a national reduction causes total EU ETS emissions to decrease. The debate seems to focus on how investors act when permits can be saved (banked) and traded later. Such financial considerations are not considered in this paper.

Instead, the purpose of this paper is to show how to handle permits in economic evaluations such as general equilibrium cost–benefit analysis (CBA). The analysis is generalized to account for a permit system where the total supply of permits is endogenous. This is an important issue for evaluations of policies that aim at reducing climate change. Without consistent evaluation rules, founded in welfare economics and general equilibrium theory, evaluations become misleading and flawed.

The paper is structured as follows. Section 2 develops the simple general equilibrium model that is used to derive cost–benefit rules. The results for a fixed cap-and-trade system and a system with an endogenous supply of permits are presented in Section 3. Section 4 generalizes the results to an intertemporal world. This generalization has a dramatic impact on how to undertake CBA when the permit cap is endogenous. A few concluding remarks and an Appendix are added.

2. The model

In order to set aside distributional issues, the focus is on a representative household. This household is assumed to be equipped with standard textbook preferences; see, for example Jehle and Reny (2011, Ch. 1). Its indirect utility function, which also serves as the social welfare function, is as follows:

\[ V(.) = V(q, w, \pi + T, z, E), \]

where \( q \) denotes a price vector, \( w \) the wage rate, \( \pi \) denotes aggregate profit income, \( T \) denotes a positive or negative lump-sum tax, \( z \) denotes a public good, below used to derive cost–benefit rules, and
$E$ denotes emissions of greenhouse gases. The profits of the representative firm producing commodity $i$ (a consumer good or a renewable or non-renewable input) is as follows:

$$\pi^i(.) = \pi^i(q, p, w, E),$$  \hspace{1cm} (2)

where $p$ denotes the permit price, with the derivative with respect to $p$ equal to zero if the production does not cause emissions of greenhouse gases. A firm using a fossil fuel, denoted $e$, whose unit price equals $q_e$ needs permits. Rescaling the price of a permit such that it reflects emissions by one unit of the fossil fuel, a profit-maximizing firm uses so much of the fuel that the value of its marginal product equals the sum of the input price plus the rescaled permit price. Formally, $q_i \cdot f^e_i(q_e, \ldots) = q_e + p$, where $f^e_i(.)$ denotes the marginal product of the fuel and $p^e$ the rescaled permit price. We term $q_i \cdot f^e_i(q_e, \ldots) - q_e$ the value of the marginal product of a (rescaled) permit.

Equation (2) highlights that production possibilities could be affected (positively or negatively) by emissions; some sectors gain while other lose from climate change.

The public sector is modelled in the simplest possible way, given the purpose of this paper:

$$T = p \cdot A - p \cdot A^G - C(a^G) - q \cdot x^G - w \cdot L^G,$$  \hspace{1cm} (3)

where $A$ denotes the number of permits issued (and auctioned), $A^G$ denotes the number of permits required in the production of the current level of the public good, $C(.)$ denotes an abatement cost function, $a^G$ denotes abated emissions, $x^G$ denotes a vector of inputs, and $L^G$ denotes demand for labour used in the production of $z$. All other activities of the government are suppressed.

Prices are flexible and adjust to maintain equilibrium in markets. Focusing on the market for permits, equilibrium is reached when the permit price $p$ is such that supply equals aggregate demand:

$$A = \sum_i A^i(q, w, E) + A^G,$$  \hspace{1cm} (4)

where $A^i(.)$ denotes demand for permits by the sector $i$ firm. A general equilibrium occurs when the price-wage vector is such that all markets are in equilibrium. This concludes the presentation of the model.

### 3. Valuing permits under exogenous and endogenous permit regimes

In order to derive project evaluation rules, we could consider a change in the production of an existing commodity or the introduction of a new one. In the present context, the choice of policy change does not matter. We chose to evaluate a small increase in the provision of the public good. This will, like any other policy change, potentially cause small price adjustments throughout the economy to maintain equilibrium in markets. This implies that induced price adjustments can be ignored. The loss of consumer surplus caused by a small increase in $q_i$ (by Roy’s identity) equals the gain in producer surplus of the price increase (by Hotelling’s lemma): $-\partial V_m/\partial q_i/V_m = \partial \pi^i/\partial q_i = x_i$, where $V_m$ denotes the marginal utility of lump-sum income and $x_i$ denotes the equilibrium quantity; see, for example, Jehle and Reny (2011, Theorem 1.6 and 3.7). Thus, $(x_i - x_i)\partial q_i = 0$. Similarly, for an input, where a supplier’s gain from a marginal price increase exactly matches a purchaser’s loss of producer surplus.

Thus, totally differentiating the social welfare function (1), the effects of induced price changes vanish – as is further highlighted by Equation (A.1) in the Appendix – and what remains are the real effects of the considered small increase in the provision of the public good. Holding the aggregate number of permits fixed, the general equilibrium cost–benefit rule reduces to:

$$\left.\frac{dV}{V_m}\right|_{dA=0} = \frac{V_z}{V_m} \int dz - qdx^G - wdL^G - p \cdot (dA^G + da^G),$$  \hspace{1cm} (5)
where \( V_z \) denotes the marginal utility of the public good, and \( V_m \) converts units of utility to monetary units. The benefits of the increase in \( z \) equals the marginal willingness-to-pay (WTP) for the additional provision of the public good.\(^4\) The production of the good requires both produced inputs and labour. These are valued at ruling market prices, implying that if an input is produced using fossil fuels, its price will reflect the cost of the needed permits. In addition, the permits the public sector firm must acquire – for example because the public sector produces concrete that is needed for the considered expansion – are valued at the ruling permit price. The public sector is assumed to abate emissions in a cost-efficient manner, that is, until the marginal abatement cost equals the permit price, then switch to purchasing permits; see, for example, Tietenberg (2018, Ch. 15) for details. Abatement efforts are kept visible in Equation (5) because they play an important role under the reformed EU ETS.

The question arises why permits represents a cost to society. The reason is that other production activities requiring permits are displaced when the number of permits is fixed. As explained below Equation (2), firms demand permits until the value of the marginal product of an input causing emissions of greenhouse gases equals the ruling permit price plus the input price. Thus, \( p dA^G \) in Equation (5) captures the value of displaced production in the rest of the economy when private sector firms ‘lose’ \( dA^G \) permits, assuming that prices adjust such that the other inputs used in the displaced production finds other uses in the economy. In other words, \( p \) is the smallest compensation a firm needs to voluntarily give up a permit when all other inputs can be used for other purposes. Similarly, production elsewhere is displaced when resources are devoted to abatement efforts.

The fact that the number of permits is fixed also explains that emissions remain constant; recall that \( E = A \), ignoring here sectors that are not covered by the permit system. Hence, because \( dE = 0 \), there is no impact on welfare through the emissions argument in the social welfare function in Equation (1) or through the corresponding argument in profit functions in Equation (2).

Turning to the case where \( A \) is endogenous, we have the following impact on emissions as the provision of the public good slightly increases:

\[
dE = \frac{\partial E}{\partial A} dA = 1 \cdot \left( \sum_i dA^i + dA^G \right) = dA,
\]

where \( dA^G = (\partial A^G/\partial z)dz \). Note that we consider the general equilibrium adjustment in total demand for permits, as captured by Equation (4), caused by the exogenous change in the provision of the public good, but conditional on the properties of the reformed EU ETS.\(^5\) For simplicity we assume that \( z \) represents a ‘clean’ technology such that \( dA < 0 \). Thus, the increased provision of \( z \) causes a reduction of total emissions. In Section 4 we will turn to intertemporal implications of an endogenous cap.

The economic evaluation of the considered project is modified as follows under an endogenous cap:

\[
\frac{dV}{V_m} = \frac{dV}{V_m} \bigg|_{dA=0} + \left[ \frac{V_E}{V_m} + \pi_E + p \right] dA,
\]

where \( V_E < 0 \) denotes the marginal disutility of emissions, \( V_E/V_m \) denotes the negative WTP for a small increase in emissions, or equivalently the willingness-to-accept compensation in exchange for a small increase in emissions, and \( \pi_E \) denotes the impact on aggregate profit income of a small increase in emissions. Thus, provided \( A \) reduces, as assumed, there is an additional benefit in comparison to the fixed cap-and-trade scenario considered in Equation (5). This is captured by the first term within square brackets. In addition, aggregate profit income increases or decreases when production possibilities are affected by the reduction in emissions; most likely, some sectors gain while others lose.

An important feature of the social cost–benefit rule (7) is that reduced emissions are valued according to (households’ and firms’) WTP, not according to some estimate of the marginal damage cost (social cost of carbon; see, for example, Ricke et al. 2018). These concepts could, but need not, coincide. There is also an additional cost as private sector firms requiring permits are displaced.
when the total number of permits reduces. As discussed below Equation (2), the permit price reflects the value of the marginal product of a permit, and production is displaced as \( A \) reduces. This can also be seen from Equation (3): public sector income declines as \( A \) reduces.

At an optimum for the permit scheme, \( p = \frac{-V_E}{V_m} - \pi_E \) and the expression within square brackets in Equation (7) equals zero. Then the market price of permits reflects the full social cost even when the number of permits is endogenous. However, as long as \( p < -\frac{V_E}{V_m} - \pi_E \), as is suggested by empirical studies, for example, Ricke et al. (2018), then the expression within square brackets in Equation (7) is negative and multiplied by a negative number, that is \( dA < 0 \). Thus, the considered project generates some extra net benefits under a punctured waterbed. However, as pointed out by Bruninx et al. (2019), Gerlagh, Heijmans, and Rosendahl (2019), and Rosendahl (2019a, 2019b), in particular for more long-run projects, it is not unlikely that \( dA > 0 \) due to the properties of the reformed EU ETS. Then, the considered project turns out to be less socially profitable under an endogenous than under an exogenous cap on emissions.

A final point deserves mentioning. Abatement is now socially profitable beyond the level where the marginal abatement cost equals \( p \) provided such an expansion causes a further reduction of total emissions \( A \) and the expression within square brackets in Equation (7) is negative. This is another novel result provided by this paper.

4. Intertemporal generalization

The atemporal analysis in the previous section might seem to fully cover the principal consequences of the reform. However, when the cap becomes endogenous, a shift in emissions in a period could affect the path of emissions over decades. For example, Carlén et al. (2019) and Silbye and Sørensen (2019), estimate that emissions by a project as late as 2035 and beyond could affect the supply of permits.

For each point in time \( t \) the project causes a kind of permit multiplier:

\[
PM(t) = \sum_{\tau=t}^{t^S} \left[ \frac{V_{E\tau}}{V_m} + \pi_{E\tau} + p_\tau \right] dA_\tau, \tag{8}
\]

where \( t \in [0, t^S] \), \( t^S \) denotes the point in time when the surplus of permits falls below its upper threshold (833 million) where an exogenous cap on emissions is reintroduced, and \( V_m \) now is interpreted as the marginal utility of present value lump-sum income. The negative present value WTP at time \( \tau \) for a marginal increase in emissions, reflected by \( V_{E\tau}/V_m \), is interpreted as capturing total damage to the household’s utility by a marginal ton of climate gases emitted at time \( \tau \); recall that this ton adds to the stock of greenhouse gases and degrades only slowly over time. The profit impact term \( \pi_{E\tau} \) has a similar interpretation: it provides the total impact on the household’s present value profit income at time \( \tau \) of a marginal ton of gases emitted at time \( \tau \). Any lag in the adjustment of the supply of permits is suppressed in Equation (8), as is also a possible impact by the project on the number of permits issued once the TNAC falls below its lower threshold (400 million).

Uncertainty remains about what pattern \( dA_\tau \) will take over time. According to some simulations, the TNAC crosses its upper threshold within a few years, while other simulations suggest that this will not occur within the next fifteen to twenty years. Some simulations suggest that a reduction of demand for permits at time \( t \) by one ton causes the sum over time of \( dA_\tau \) to be negative (often in the interval \([-0.9, -0.4]\)) but there are also those suggesting that the sum could be positive. The outcome depends critically on assumed parameter values; see, for example, Bocklet et al. (2019), Bruninx et al. (2019), Carlén et al. (2019), Gerlagh, Heijmans, and Rosendahl (2019), Rosendahl (2019b), and Silbye and Sørensen (2019). However, the focus here is on the impact of the reform on how to undertake economic evaluations of projects/policies, not to contribute to the discussion of how the reform actually affects the path of emissions.

Equation (8) is valid until the cap on emissions is once again binding. Onwards, we are back in the kind of world covered by Equation (5). Summing up and slightly generalizing the cost–benefit
rule we have:

\[
\frac{dV}{Vm} = e^{-rt} \cdot \sum_{t=0}^{t^1} \left[ \frac{V_{m}^{z_{1}}}{V_{m}} dz_{t} - q_{t}dx_{t}^{G} - w_{t}dL_{t}^{G} - p_{t} \cdot (dA_{t}^{G} + da_{t}^{G}) \right] \cdot e^{-r \cdot t - d\bar{I}} + SV(t) + \sum_{t=0}^{t^1} PM^{PV}(t) \cdot e^{-r \cdot t},
\]

where \( t^0 \) denotes the date when the project becomes operational, \( r_t \) denotes the time \( t \) real discount rate, \( t^1 \) denotes the point in time when the project is terminated (assuming that \( t^1 \geq t^S \) but that EU ETS is operated beyond \( t^1 \)), \( dI \) denotes the present value at time zero of the investment cost (assumed to include the cost of permits needed during the construction phase), \( SV(.) \) denotes any present value at time zero of remaining infrastructure at the time operations cease, and \( PM(t) \) in Equation (8) has been converted to a present value at time \( t \). The first line contains the fixed-cap present value CBA, except an initial investment cost and a scrap value which are added in line two. The effects are discounted to time 0 using either a constant discount rate or a rate that typically is assumed to decrease over time (hyperbolic discounting). The second line adds the present value of each permit multiplier from the beginning of the project until the EU ETS returns to being a fixed-cap scheme and converts each \( PM^{PV}(t) \) to a present value at time zero.

If the project has an impact on time \( t \) emissions outside the EU ETS, for example through its demand for inputs produced in other parts of the world, there is a once-and-for-all effect equal to \( \frac{V_{m}}{V_{m} + \pi_{E_t}} \) per ton of emissions, where \( V_{E_t} \) and \( \pi_{E_t} \) have the same intertemporal interpretations as above (and are discounted back to time zero). This effect is added to the CBA in Equation (9). Thus, and in sharp contrast to emissions within the EU ETS, there is no path impact (permit multiplier) of the kind found in the second line of Equation (9). Emissions occurring outside the EU ETS are valued in one and the same way regardless of whether there is a fixed or endogenous cap within the EU ETS. The path impact occurs only when there is an endogenous cap on emissions and only for emissions within the EU ETS.

Equation (9) ignores any target a country or the Union might have for their total emissions. For example, the Paris Agreement, which entered into force in 2016 (United Nations 2015), could mean that the change in emissions covered by the permit multipliers in Equation (9) are ‘neutralized’ by other policy measures. Even though it seems unlikely that measures can be designed with such surgical accuracy that they counteract the change in emissions caused by individual projects, in the aggregate and ex post the sum of impacts by projects could be counteracted. What remains of the permit multipliers is then the present value of the increase or decrease in permits (the present value sum of \( p_{t}dA_{t} \)) less the present value cost incurred or avoided for a countermeasure such that the sum of \( dA_{t} \) in Equation (8) is exactly matched. For further discussion of this case, the reader is referred to Johansson (2020).

5. Concluding remarks

Cap-and-trade schemes cause trouble for those undertaking cost–benefit analysis. Some manuals, such as the one by the US EPA (2010), seem to consider permits as pure transfers. Other manuals, for example the one by the European Union (2014), value emissions at the social marginal cost of greenhouse gases. As this paper shows, these are inappropriate approaches. Under a fixed cap-and-trade scheme, a project required to possess permits to cover its emissions of greenhouse gases has no impact on emissions within the ‘bubble’, here EU ETS. The additional emissions caused by the project are balanced by equally sized emission reductions elsewhere within the bubble.

The permits should be valued at the ruling permit price. The reason is that this price reflects the value of displaced production when other agents ‘lose’ permits; recall that under a conventional cap-and-trade scheme there is a fixed number of permits. Treating permits as transfers, hence ignoring them, or valuing emissions at a global marginal damage cost results in flawed evaluations.
The recent reform of the EU ETS transforms the scheme from a fixed cap-and-trade system to a system with an endogenous supply of permits. Projects could affect the path of emissions over decades, but the ongoing debate between economists highlights that much uncertainty with respect to the functioning of the reformed scheme remains.

The reform has important implications for economic evaluations of projects either requiring permits or aiming at a shift away from fossil sources to renewable ones. In a sense we turn to two-part evaluations. One part evaluates the considered project or policy conditional on the initial number of permits. This is the fixed cap-and-trade part of the CBA. In the second step one examines if the project/policy has an impact on the number of permits within the EU ETS. Any impact is valued according to a tripartite scheme. A reduction in emissions is valued according to households WTP. Any positive or negative impact on aggregate profits through climate-related productivity effects is added. Thus, at least according to theory, these effects are not measured using some estimate of saved social costs of carbon (but practitioners might find such estimates a reasonable shortcut). Fewer permits imply that production is displaced. The market price of permits is used to assess this cost. Thus, just estimating the benefits of less climate gases results in a flawed evaluation, overestimating the project’s social profitability. These results are reversed if the project causes the total number of permits to increase.

The permit multipliers imply that emissions within the reformed EU ETS are valued differently from emissions a project causes outside this scheme. There are no permit multipliers associated with the latter kind of emissions, regardless of whether they occur inside or outside the European Economic Area. The permit multiplier is a unique feature of the reformed EU ETS.

A final novel result is that with a punctured waterbed, that is, an endogenous cap, abatement efforts should be taken beyond the point where the marginal abatement cost equals the permit price. This is so if this causes a further reduction of emissions (and the associated net benefits exceed the permit price). It seems legitimate to subsidize abatement efforts if they replace permits under a punctured waterbed.

Notes

1. The UK will remain in the EU ETS until the end of 2020. Therefore, the Carbon Emissions Tax (CET), which would have replaced the EU ETS in a no deal scenario, has not yet been commenced.

2. Johansson and Kriström (2016, 2018) discuss how to assess a fixed cap-and-trade scheme, while Jorge-Calderón and Johansson (2017) consider such a system in terms of an airport investment.

3. Emissions outside the ‘bubble’ are addressed in Section 4. Issues like the treatment of emissions of other gases and particles, taxes and market power are outside the scope of this paper.

4. If the project instead had provided a marketed good, for example electricity, the market price of this good had replaced \( V_c/V_m \).

5. Because \( dA = dE \) appears also in the right-hand side, \( (\partial A/\partial E)dA \), there is an endogeneity, that is, we could move these effects to the left-hand side to obtain a further multiplier effect.

6. Jorge-Calderón and Johansson (2017, 254) introduces a ‘target-consistent’ approach, where a project causing emissions forces the decision-maker to increase an emission charge to keep total emissions constant. Other possible measures include forest plantations and clean cooking solutions in low-income countries.

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Appendix

To arrive at Equation (5), totally differentiate the social welfare function (1) to obtain:

\[
\begin{align*}
\frac{dV}{dA} = & \ V_m \cdot [(x' - x^d - x^G)dq + (L^s - L^d - L^G)dw \\
& + (A - \sum_i A^i(q, w, E) - A^G)dp \\
& + \frac{V_z}{V_m} dz - qdx^G - wdt^G - p \cdot (dA^G + da^G)],
\end{align*}
\]

where a superscript \( s \) \((d)\) refers to supply (private demand), any sign indicating transposed vectors is suppressed, and prices clear markets so that all terms in the right-hand side of the first two lines sum to zero. The expression in the third line coincides with Equation (5).