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# Carbon Emission Values in Cost Benefit Analyses

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**Abstract**

New infrastructure projects may affect $CO_2$ emissions and, thus, cost benefit analyses for these projects require a value to apply for $CO_2$. The value may be based on the marginal social cost associated with emissions or on the shadow price resulting from present and future policies geared towards $CO_2$ emissions. In the present paper it is argued that the social cost approach should be seen as preceding the shadow price approach. Both are thus necessary, but for cost benefit analysis of infrastructure projects we argue for the shadow price approach as the primary tool. There is a series of complications involved when applying this principle in practice. Several of these are discussed in the paper, including non-marginal projects that affect permit prices, non-transparent permit markets, different instruments capturing different aspects of a $CO_2$-value, multiple policies present simultaneously etc.

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## Introduction

Investments in infrastructure projects, *e.g.*, new highways, high-speed railways, or airports, will potentially have an impact on $CO_2$ emissions. It may be that a new highway results in more people using cars rather than public transport, or it may be that cars can be used in a more efficient manner. Infrastructure investments are often the responsibility of a government, typically with limited resources at its disposal. To facilitate an efficient use of the resources, investments like these are frequently preceded by cost-benefit analyses (CBA). The present paper aims at discussing how expected changes in $CO_2$ emissions due to the investment in question are to be handled in the CBA. In particular, the paper addresses principles behind what value to attach to a change in $CO_2$ emissions in a CBA framework.

In a guide on CBA prepared for the European commission, Florio et.al. (2002, page 125) defines CBA as a "*conceptual framework applied to any systematic, quantitative appraisal of a public or private project to determine whether, or to what extent, that project is worthwhile from a public or social perspective. Cost-benefit analysis differs from a straightforward financial appraisal in that it considers all gains (benefits) and losses (costs) regardless of to whom they accrue.*" Thus, CBA:s need to consider factors that are not dealt with – at all or in an incorrect way – by the market. $CO_2$ emissions may serve as a typical example to the extent that there, without any governmental intervention, will not emerge a market for them. Such externalities are typically not addressed in a financial appraisal, but should be addressed in a CBA as they constitute a loss (or a gain) to people in the society.

The rest of the paper starts with a discussion of potential approaches to derive a $CO_2$ value applicable in a CBA. The two major options considered are a direct approach under which one tries to establish the social cost of emitting an extra tonne of $CO_2$ and an indirect approach where one derives the value through the shadow price of $CO_2$ policies. This discussion is brief as both approaches have been adressed earlier, *e.g.*, Watkiss and Downing (2008) and Clarkson and Deyes (2002). Following the introduction of the approaches we will argue that, given a set of assumptions, the latter is more suited for the purposes addressed here, *i.e.*, to estimate a $CO_2$ value for CBA:s on infrastructure projects. Having established this principle, and under which circumstances it is relevant, we turn in section 3 to a discussion about practical applicability, limitations and problems. Section 4 concludes.

## Potential approaches to derive the $CO_2$-value

One can think of several ways to establish a $CO_2$-value suited for use in a CBA. In particular there are two distinctly different, though highly related, approaches; the social cost of carbon and the shadow price of carbon policy. The former may be viewed as a 'direct approach' and the latter as an 'indirect approach'. In this section, the background of these two approaches will be given a brief presentation followed by a discussion on there applicability in a CBA setting.

*Direct approaches*

The marginal social cost of carbon (SCC) is the cost one additional unit of carbon, in the form of $CO_2$, into the atmosphere will cause the society as a whole. There are two complicating matters: First, it is not the flow, but the concentration of $CO_2$ in the atmosphere that affects the climate. Second, $CO_2$ remains for long periods in the atmosphere. The cost an extra tonne $CO_2$ emitted today causes the society is thus the discounted value of the (monetized) damage it causes during the period it remains in the atmosphere.

To calculate the damage for each future period, one needs an assumption regarding the path of future emissions, *i.e.*, a baseline to compare with. The SCC is thus the present value of the monetized damage caused each period of emitting one extra tonne $CO_2$ today as compared to the baseline. One extra unit of emissions may cause more damage under a scenario with high baseline emissions, than in a low emission baseline scenario. Consequently, the estimate of the future baseline may be crucial for the result, which adds to the uncertainty surrounding the value estimates.

Depending on what one assumes about future emissions, the social cost of carbon may be estimated in, basically, two different ways. The difference between the two lies in the design of the baseline. In one approach, the baseline is the optimal path, *i.e.*, a path at which the marginal costs of abatements equal the marginal benefits from abatements. The other approach calculates the present value of future damages for any – not necessarily the optimal – path. Both approaches call for a substantial amount of calculations and typically requires, so-called, Integrated Assessment Models (IAM:s). These models aim at combining the understanding we have about the natural mechanisms behind climate change with monetized benefits and costs and thereby arrive at guidelines for optimal policy now and in the future.

In recent years, several studies reporting SCC estimates using different IAM:s and various settings have been published. Figure 1 exhibits a histogram constructed using data from Tol (2008) which looks at 211 SCC estimates from 47 studies[1]. The mean value is \$104.80 per tonne C (~0.20 SEK/kg $CO_2$)[2], but the distribution is skewed so the median is considerably lower; \$29 / tC (~0.06 SEK/kg $CO_2$). The estimates range from -\$6.60 per tonne C[3] (~-0.01 SEK/kg $CO_2$) to \$2400 per tonne C (~4.58 SEK/kg $CO_2$). The middle 50 per cent of the estimates are found within the range of \$10 to \$90 / tC (~0.02 to 0.17 SEK/kg $CO_2$).

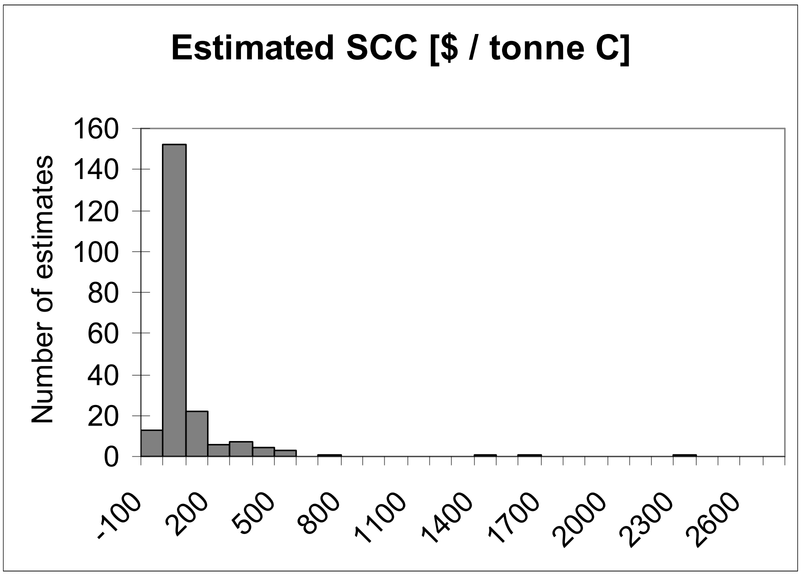


***Figure 1**, Histogram of 211 SCC estimates from 47 studies. Based on data in Tol (2008)*

The fact that the SCC is hard to estimate is in itself not a reason to dismiss these direct approaches. Even less is it a reason to ignore the problem by applying a zero value. As noted by Pearce (2003, p.3); "*If there is uncertainty about a social cost estimate, that uncertainty does not magically disappear by not adopting the social cost estimate*". Even so, the large spread in estimates serves as an illustration of the difficulties in finding *the* $CO_2$ value to apply in a CBA.

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[1] Tol (2005, 2008) and Brännlund (2009) examine these studies in more detail, for example by comparing peer-reviewed with non-peer-reviewed studies, and more recent studies with older ones.

[2] The conversion uses \$1 = 7 SEK and that one unit $CO_2$ weighs 3.67 times one unit C.

[3] Negative values are due to an initial positive impact on crops etc. For higher concentrations this is reversed.

*Indirect approach*

The shadow price of carbon policy is an alternative approach, which takes its starting point in that existing policies create a cost per unit of emission for the regulated agents. This cost may be more or less difficult to observe. In some cases however, it is a rather straight forward exercise to at least arrive at a reasonably precise (marginal) cost estimate. In particular this is the case when the regulation is either by the means of an emissions tax or a by a tradable permits scheme that establishes a market clearing price for the permits. Both in the case with an (homogenous) emissions tax and a well designed emissions trading scheme[4], the tax or the resulting permit price will be a good measure of the marginal abatement cost in the economy. This follows from that the agents have incentives to reduce their emissions up to a point where additional reductions would cost more than paying the tax or covering the emissions with permits.

As noted for instance by Clarkson and Deyes (2002), to use the permit price as a proxy for the social cost of an additional unit of $CO_2$ emissions is not without problems. In particular, this is due to the circularity in that the approach relies on that political decisions create a system which puts a price on emissions, but information regarding the expected social costs is required for the policy maker to make the decision.

The indirect approach is also associated with large uncertainties, even though these arguably are substantially smaller than those surrounding the direct approach. We will return to discuss this in more detail below.

*Which approach to use?*

The principle behind CBA is that all resources required for a project should be accounted for in the analysis. This includes resources for which there is no market. Thus, if a project will result in people being exposed to noise this is to be considered a cost, *i.e.*, it is to be seen as spending the valuable resource ‘silence’, that should be taken into account in the CBA. This seems to favour the direct approach, *i.e.*, the value to be attached to $CO_2$ reductions (or increases) in a CBA is the social cost of carbon because it would provide a direct estimate of

[4] That is, one which keeps transaction costs low, does not result in that any agents receive market power, and provides transparent information to the market *etc*.

the monetized damage. This is also a conclusion drawn in some other studies, *e.g.*, Brännlund (2009) and Clarkson and Deyes (2002). There are however two major problems with this approach. First, as noted above, there are huge uncertainties in several dimensions involved partly due to a series of scientific issues that are yet to be resolved. Second, the social cost of carbon approach does not take the existence of policy measures into consideration, which we subsequently argue that a valid approach should.

The first is in itself not a reason to discard the social cost of carbon approach. As a CBA of the kind we are interested in here is forward looking, basically all values in it will be subject to uncertainty. The value attached to $CO_2$ may be more uncertain than many other values. However, this does not imply that the social cost of carbon approach is wrong, only that it is harder to – from the great range of estimates conducted – decide on which value(s) to use in the analysis and that the uncertainties must be dealt with in the analysis. One can think of several ways in which one may go from the range of estimates to a single value, or at least a small number of values. One can adopt a technical approach, *e.g.*, choose the mean value, or one can have a group of experts decide. By such procedures any obvious errors or outliers may be avoided, but due to the nature of the problem, *e.g.*, the fundamental uncertainties involved, no procedure may guarantee that the 'correct' value is chosen.

This suggests that one should use the same approach as used for many other difficult questions in a democratic society. Namely to let the politicians/policy makers decide. We expect the policy makers to, at least partially based on the scientific findings in the field, weigh different interests towards each other to arrive at a policy, *e.g.*, an emissions tax system or a tradable permit approach, which incorporates the 'political' social cost of carbon. This includes taking future generations' wellbeing into consideration, weighing the utility of different groups towards each other, forming a judgement on the impact from low probability/high cost events to name but a few of a whole list of highly complex issues calling for attention.

The 'political' social cost of carbon may – and almost certainly, will – differ from the 'true' social cost of carbon[5]. But as long as there is no way to exactly determine the true cost, there

[5] A 'true' social cost of carbon depends both on the natural mechanisms, which follow the laws of physics and may thus result in an objective true outcome, and the preferences, which differ between individuals. Thus, the term 'true' should here be interpreted as the cost applicable if all relevant information could be observed.

seems to be few alternatives that improve the situation in an objective way. There are most likely groups who desire higher $CO_2$ values (or who claim that the true value is above the political one), and other groups who would like them reduced. In both cases, they are free to provide the policy maker with information to back up their claims.

A consequence of this view is that the question is not whether the policy maker should adopt the direct or the indirect approach when deciding on which $CO_2$ value to use in CBA:s. Rather, the direct approach, *i.e.*, the social cost of carbon estimates, is one input to a policy process which, as an output, will result in a (shadow) price. This shadow price may be interpreted as a manifestation about the political cost of carbon.

This leads to the second problem with the direct approach. Once the policy maker has established a policy, this must be taken into consideration when deciding on the value for the CBA. Thus, the fact that there currently – and probably also in the future – exists a set of policies towards $CO_2$ will influence the $CO_2$ value applicable in a CBA. We will return to the complicating circumstance of having numerous different and interdependent policies in the next section.

Consider the stylized case where a majority of the global $CO_2$-emissions are covered by a homogenous emissions tax. If an infrastructure investment leads to expected reductions in $CO_2$ emissions, how would these be valued in this tax setting? Using some other valuation than the global tax would lead to efficiency losses due to a lack of cost effectiveness. If the value applied in the CBA is larger than the tax, the resulting reductions in emissions could have been achieved at a lower cost somewhere else in the economy. One might however argue that if the true social cost of carbon is larger than the global tax, there is nevertheless a gain in carrying out the project that may outweigh the loss from it not being cost effective. However, if one accepts the discussion above regarding the actual policies being a manifestation of a political social cost of carbon, this becomes mere speculations as there is no way to observe the true social cost of carbon.

Even though there are objections to this discussion, see for example Pearce (2003), we will leave the global tax setting by noting that from a practical perspective the permit trading approach is more in line with the current actual policies. Furthermore, even if an internationally harmonized carbon tax has several appealing features, it is associated with a series of problems making it a less likely candidate for future policies, see, e.g., Pearce (1991), Pizer (2002) and Bohm (1997).[6]

Thus, rather than a tax regime, consider the case where there is an agreement that specifies an upper limit of emissions from the participating parties and that, to facilitate cost effectiveness, parties may trade in emission permits. What are the implications of an investment in infrastructure that, say, results in that people commute by train rather than by cars? The most important thing to note is that total emissions are not affected as these are fixed through the permit trading scheme. If the project is large enough, permit prices will decrease – but in a context where the permit trading scheme is global, or at least cover a large share of the global emissions, the project must probably be huge to have anything but negligible impact on the permit price. In a similar manner, the project may influence future policy decisions on total emissions, *e.g.*, the investment in infrastructure justifies the policy maker to set a more stringent cap than otherwise would be the case. Again, this would seem to require very large projects. Nevertheless, the possibility cannot be ruled out and we will return to it below.

The main consequence of the investment however lies in that other emitters do not have to reduce their emissions to the same extent as without the project. That is, what in the absence of a trading scheme would have been emission reductions is now rather a reallocation of abatement efforts in the economy. To facilitate the presentation let us refer to reductions in emissions that are caused by the project, but countered through the trading scheme, as 'quasi-reductions'. As reducing emissions is costly, the quasi-reductions are associated with a value corresponding to the costs other emitters would have had in the absence of the project. That is if emissions are covered by a tradable permit scheme, any quasi-reductions in $CO_2$ emissions generated by a project should be valued at the market price for emission permits, since the permit price reflects the marginal cost of abatements which now are avoided. Thus, in order to correctly capture the effects of the project, the $CO_2$ value used in the CBA should be equal the shadow price generated by climate policy. Implicitly, this assumes a hierarchy in policy decisions in that the CBA, and thus the decision regarding investing in the particular infrastructure project, depends on the climate policy decision.

[6] Noteworthy, there are recent studies that argue the problems with international and harmonized taxes may be avoided, see Nordhaus (2007) and Cooper (2008).

To summarize, we have put forward two claims. Claim 1) states that policy makers/politicians use scientific findings about the likely social cost of carbon when designing policy and, thus, their decisions may be viewed as a manifestation of their judgement about a valid cost. We refer to this as a ‘political’ social cost of carbon, and acknowledge that this most probably will differ from a ‘true’ social cost of carbon. However, as the latter is not observable, we will not know to what extent or even in which direction the two deviate. Claim 2) states that the existing policies geared towards $CO_2$ will determine what value on $CO_2$ emissions should be used in a CBA.

In a situation with a (semi-)global tradable permit scheme the, perhaps more controversial, first claim may be disregarded as the scheme per definition has fixed the total emission in the scheme. Whether or not the marginal abatement cost is equal to the true social cost of carbon is then of limited interest.

**Practical implications, problems and limitations**

At least as long as there is a tradable permit scheme in place, the discussion above suggest that the problem is rather straight-forward; the permit price should be used in the CBA as it reflects the value of the reallocation of abatement efforts following from the project. This principle is transferable to real life situation even though there are then a series of complicating circumstances typically present. In the following we will address some of these.

*Non-marginal projects*

A marginal project is small relative to the entire market for tradable permits such that the project’s influence on the permit price is negligible. For such projects the discussion above applies and we should use the market value of the permits as a correct measure of any changes in $CO_2$ emissions due to the project.

A non-marginal project is thus large enough to have an impact on the permit prices. As noted above, this would seem to require projects of substantial proportions. Consider a project that would result in quasi-reductions of $CO_2$ large enough, say $Q$ units, to reduce the permit price from an initial level of $P_1$ to $P_2$. What is then the correct $CO_2$ value to use in the CBA; $P_1$, $P_2$ or something else?

Following the same logic as presented above, there will be a reallocation of abatement burdens, but the total amount of emissions will still be fixed. The value of the project lies in that other may reduce their abatement efforts as compared to a situation without the project. We know that the “first” marginal unit of abatement that is made unnecessary due to the project has a value of $P_1$, since that is the value of the marginal abatement prior to the project. We also know that the “last” unit has a value corresponding to $P_2$ as that is the new permit price after the completion of the project. The path between those two points, however, is not known. A plausible approximation is that the total value of the project’s impact on $CO_2$ may be given by $Q\ (P_1 + P_2)/2$.

*Quasi-reductions occur over time*

Project such as the ones discussed here are long-lasting. As a consequence, they will have an impact on $CO_2$ emissions for many years to come. The problem from a cost-benefit analysis perspective is then that we need a good estimate of the $CO_2$ values valid in the future. As discussed above, this is very difficult – but it is inherent in the nature of all investment decisions and simply cannot be avoided.

The first thing to note is that the difficulties in estimating future values do not imply a change of the underlying principle. We are still in pursuit of the values created by (future) quasi-reductions and these values are still given by the (future) permit prices, as these will reflect the then prevailing marginal abatement cost in the economy.

A good starting point would be to look at the futures market for permits. Most likely this will not reveal the prices actually valid in the future – but, as long as the market is functional, it provides information about the market’s ‘best guess’. As it is the market value of the permit we are seeking, this is desirable. However, one needs to keep in mind that these markets are currently not very transparent, something we will return to below.

There is also a complicating causality problem present in that future permit prices affects whether a project should be carried through while, simultaneously, the future prices are affected by the existence of the project. As long as the project is marginal as defined above, this is a minor complication. For non-marginal projects it may significantly increase the difficulties of estimating the future prices.

*The interconnectivity between future permit prices and future climate policy*

A potentially more complicating matter from a $CO_2$ value perspective than when non-marginal projects influence future permit prices lies in a similar interconnectivity between future permit prices and future climate policy. A policy maker concerned with efficiency would allocate a number of emission permits to the market such that the expected marginal abatement costs, which corresponds to the expected price, equals the expected marginal benefit from abatement. If the marginal abatement costs are reduced, the policy maker would typically reduce the number of permits thereby making the system more stringent. Thus, even if the emissions are fixed through the trading scheme in the shorter run, in the longer run the scheme will be calibrated and the project may influence this calibration.

Again, the project must be very large to have anything but negligible impact on future climate policy. Nevertheless, there is an important observation to be made in that future calibrations of the trading scheme probably will dampen the fluctuations in permit prices. If, for instance, a new technology that makes abatement much cheaper is introduced, permit prices will drop *ceteris paribus*. As the optimal response from the policy maker then is to set a more stringent target (than if the new technology had not been introduced) the price drop will at least partly be countered.

*Several policy goals are present at different levels*

It is currently the case that there are several different $CO_2$ related policies working at different levels of the society. Climate change is a global problem, and the localisation of $CO_2$ emissions is not important for its impact on the climate. Thus, at the top of the hierarchy would be a global agreement and the targets specified therein. The closest we currently have to a global agreement is the Kyoto protocol. At a level below this there are multinational agreements such as the EU's climate policy. Below that there are national policies and regional policies of even smaller size. To further complicate the situation, there are often different goals for different sectors on a given level, *e.g.*, the household and transport sector within a given nation may face different $CO_2$ targets. For each of these levels and targets we may, at least in theory, derive a shadow price, *i.e.*, what price on $CO_2$ would be required to meet the target. Most likely these shadow prices will differ between the different levels. So, which value should be used in the CBA?

If we assume that the targets are expressed in quantitative terms, a similar reasoning as put forward above goes; a project that yields (quasi-)reductions of $CO_2$ will result in that other emitters covered by the same target as the project may reduce their emissions less than otherwise. The value of this, as before, may be derived using the shadow price created by the target in question. This thus points toward using the "closest" binding target. That is, if the project affects transportation and there is a specific binding $CO_2$ target for transportation, then the shadow price following from that target is the relevant one if it binds. However, if the target in the transportation sector is not stringent enough to fulfil the national target the latter must be associated with a higher shadow price. One way to approach this would be to view the different levels as a chain of targets. If different targets apply at different levels, so will the resulting shadow prices. By choosing a $CO_2$ value which answers to the highest shadow price of the chain, no target will be violated.

This approach is in line with the arguments put forward above and has the much appealing feature of not violating any of the targets. Even so, it is clearly not without problems. For instance, it opens up for strategic behaviour in the sense that a regional government may implement a policy that affects the outcome of the CBA and thereby the possibility of receiving infrastructure (partly) financed by the national government. Thus, there are reasons to question if the shadow prices from regional or sector specific targets are suited as a base for the CBA $CO_2$ value. The claims put forward above help us in sorting out the questions, but they do not provide a clear answer. However, it seems reasonable to restrict the potential targets to those that are binding and issued by authorities that may enforce them. Thereby, the problem with strategic behaviour is at least partly avoided.

However, there is an additional circumstance that provides a strong argument for using the shadow price following from a global policy in that there is an international market for emission reductions. In order to decrease global emissions one may purchase an emission permit but rather than using it to cover emissions, it is handed in to the UN. That is, one should – at least not from a pure climate perspective – never implement a policy that results in a shadow price exceeding the international permit price (relevant at the time of the reduction). Doing so implies that one forces agents in the economy to conduct measures that are unnecessarily costly and thus waste resources. Two important things must be noted. First, this only provides a principle, knowing what value the principle corresponds to is still a difficult question as discussed above. Second, to a large extent this principle is more about what targets the policy makers on different (sub-global) levels may apply than what $CO_2$ value to use in CBA. If policy makers ignore cost effectiveness and persist in designing policy that is not aligned with the overarching global policy, the resulting shadow prices should be used. However, it would seem that such policies are either badly design (as they effectively are wasting resources) or are designed to capture something more than quasi-reductions in $CO_2$.

The latter will be returned to subsequently. Regarding the former, it may be the case that badly designed policies are less likely to survive and thus policies that yield shadow prices far from the international price of emission reductions are likely to be revised over time. This may influence the chosen level of future $CO_2$ values in the CBA.

*Several policy systems are present simultaneously*

Thus far we have addressed a setting in which emissions are regulated through one single mechanism, which may seem appropriate since the mechanism should handle one single environmental problem. However, in real life there are often multiple instruments in use simultaneously. There may be circumstances under which this is justified, Bennear and Stavins (2007) and Mandell (2008).

The large number of different instruments makes it particularly difficult to achieve an overview of the system. Thus, deriving a $CO_2$ value for CBA:s becomes even more complicated. With respect to the discussion above, there is a particular problem present in the different tradable permits and taxes being in place in that they point towards different values. To an extent this is a similar problem as the vertical levels discussed above, and the guidelines are the same – one needs to consider what the value of an quasireduction is in the particular setting. This value may differ between if the project influences emitters subject to, say, EU-ETS as compared to a non-trading EU sector as transportation[7].

A related question pertains to the different permits that are traded at different prices. For instance there are EAU (the permits traded within agents in EU-ETS), ERU (permits generated through Joint Implementation under the Kyoto protocol), AAU (tradable permits allocated to liable parties under the Kyoto protocol) and CER (permits generated through the Clean Development Mechanism). To further complicate matters the latter two come in different shapes. For CERs there are primary CERs (pCER) that are permits generated directly from a future flow of emission reductions from the actual projects. These are generally associated with higher risk than secondary CERs (sCER) that are permits already generated by projects and now traded on the secondary market. Consequently, the price for

[7] It is worth repeating that this may be an indication of a sub-optimal policy mix, but that there may also be reasons, *e.g.* differences between the sectors' risk for carbon leakage, that may justify price differences. See, *e.g.,* Mandell (2010)

pCER is lower than sCER. The trade in AAUs is very limited and not transparent. One reason is the reluctance of getting hot air into the system[8]. To counter this, there are so called 'greened' AAU's that are backed up by projects that reduce emissions (Green Investment Schemes, GIS). From a legal point of view, there is no difference between green and normal AAUs, but it may nevertheless be a price difference between the two if green AAUs are considered more acceptable.

For arbitrage reasons the prices for the different permits should follow each other. In particular the price of EAUs and CERs will be highly correlated since both may be used by agents subject to EU-ETS to cover their emissions. They are however not identical, *e.g.*, the CERs may only be used to cover emissions up to a limit (which differs between nations), and typically the EAU has a higher price than the CER even though their prices tend to move together closely.

Here, we are looking for a value that captures the marginal cost of abatement for reductions that may be influenced by the project subject to the CBA. Thus, permit prices that are likely driven by something in addition to abatement costs should be avoided. For instance, EUA prices are better than sCER since the latter is associated with restrictions not directly linked to the $CO_2$ target. Both the sCER and the EUA prices are easily observable as they are traded on open market platforms. Figure 2 plots the prices for futures in EUA contracts changing hands on the European Climate Exchange December 2009 to 2014. Each observation is calculated as an average of the observed prices for 2008 and 2009. There is an evident variation between the years; a futures contract for, say, December 2012 costs less in 2009 than in 2008 – presumably due to the financial crisis. Another observation is that a contract valid further into the future costs more, which serves as an indication that the market believes that the European climate policy will remain and perhaps become more stringent over time.

[8] Hot air refers to allowances some nations receive under the Kyoto protocol in excess of their business as usual emissions.

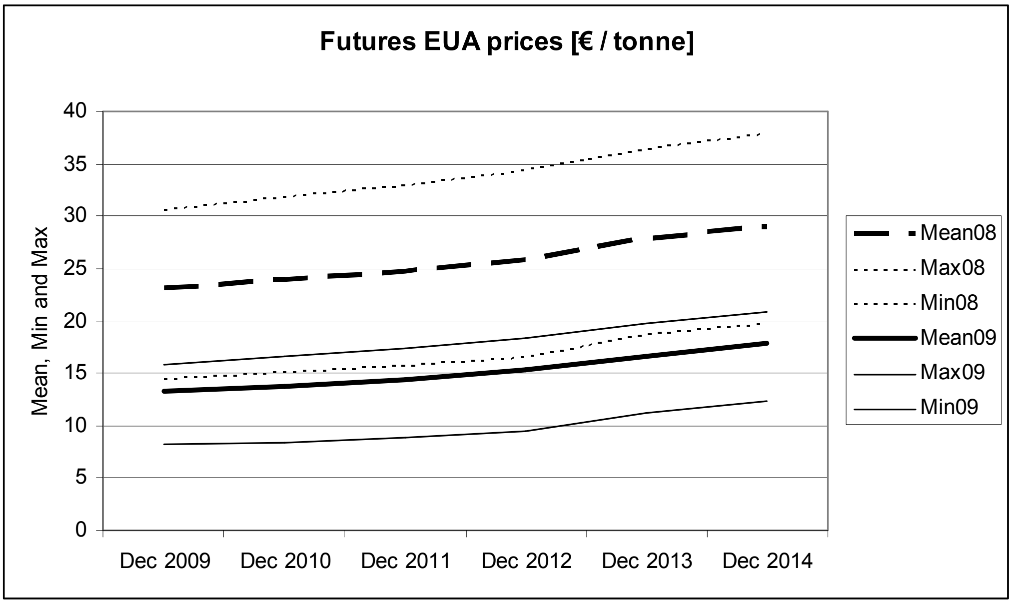


***Figure 2**. Futures prices for EUA (€ / tonne). The bold lines show mean values for contracts valid December 2009 through 2014, the thin lines are min and max values. Broken lines show trade occurring 2008 and solid lines trade under 2009 (up until November 4). Future contracts for Dec 2013 and 2014 were not traded before April 8, 2008. Data from the European Climate Exchange.*

Presently, the markets for AAUs is far from being as transparent as the EUA or CER markets. Additionally, the trade is further complicated by the green versus normal AAUs. Thus, even though the price for AAUs would in principle provide a good indication of the marginal abatement cost on a larger scale it is questionable if that market currently is sufficiently functional to provide that information.

*Are there any reasons for a government to deviate from the principles above?*

Above we have noted that it does not matter from where or from what source a unit of $CO_2$ emission origins, the impact on climate will be the same, but also that the shadow prices applied on $CO_2$ emissions tend to vary between sectors, regions etc. As the true SCC is independent of source, at least some shadow prices must be wrong. An adequate question is, thus, are there any valid reasons for a government to apply different $CO_2$ values for different sectors?

Again, this question contains two different dimensions. Firstly, there is an overarching question regarding whether policies that result in different shadow prices may be justified.

Secondly, given the presence of such policies, justified or not, how will this influence the $CO_2$ values in a CBA? To a large extent these dimensions have been addressed above, where we have argued that when choosing the $CO_2$ value the (future and present) policies should be taken as given.

However, there is one additional relevant aspect. Namely that the $CO_2$ value applied in the CBA should capture the value of changes in (quasi-)reductions of $CO_2$, nothing else. This is of particular importance, because the sole purpose of a CBA is to provide transparent information regarding whether or not to conduct the project in question. As a consequence, it is desirable that $CO_2$ policies that are partly motivated by, say, increasing the incentives for technological progress, are labelled as such in the CBA and not as general $CO_2$ policies. Of course, this applies to the policies as such – but given their existence, it may prove useful trying to disentangle the pure $CO_2$ emissions motivated part from other "hidden" motives, *e.g.*, to protect the competiveness of domestic industry, to induce further technological progress, to influence emissions that covary with $CO_2$ emissions, or to provide an example for other nations to follow, to name but a few. All such other effects may be important and should be considered in a CBA, but hiding them in a $CO_2$ price fits badly with the primary reason of conducting a CBA.

**Concluding remarks**

This paper contains a discussion about underlying principles of importance when deciding on a value to apply on $CO_2$ emissions in CBAs. It is important to note that the discussion has been focused on CBAs for infrastructural investment as it is not applicable for CBAs on climate policies. The first question addressed is whether the value should be based on the social cost of carbon, *i.e.*, the discounted social damage caused by a unit of emissions, or on a shadow price created by present and future policies.

The discussion may be summarized in two claims. The first is that as long as science can only provide a range of estimates of the (marginal) social cost of $CO_2$ emissions, choosing which value to apply is ultimately a task for politicians/policy makers. This is not an uncontroversial claim as one may argue that, say, a group of scientists are more likely to arrive at a value close to the true – but unobservable – value. The second claim is that the choice of value to put into the CBA cannot ignore existing and future policies. Given the type of CBA we address, the second claim would seem to be less controversial than the first.

From this we conclude that the question is not which approach, social cost of carbon or shadow price, should be applied. Rather, both approaches are required, but at different stages of the process. The social cost of carbon is necessary to provide input to the political process. This process will, as an output, provide a set of policies and this set is what generates the shadow prices, which provides the base for the $CO_2$ value in the CBA. This conclusion stands in contrast to some earlier studies, *e.g.*, Clarkson and Deyes (2002). However, it is in line with other. Of particular importance is perhaps that it is in line with HEATCO's (2005)[9] recommendations but, interestingly, for slightly different reasons. In HEATCO it is argued that the shadow price is a second best approach as the social cost of carbon – which would be the first best – is not observable. We argue that the $CO_2$ value shall be derived from existing and future policies, disregarding whether or not the true social cost of carbon is observable.

We have also argued that under a cap-and-trade regime, in contrast to an emissions tax approach, the first, and more controversial, claim is basically not required to arrive at the conclusion above. The reason is that under a cap-and-trade regime the aggregate emission level is fixed, and thus whether or not the regime is designed using the 'correct' social cost of carbon or not has no impact on the CBA's $CO_2$ value.

Having established a principle applicable in a stylized setting, we devote the remaining paper to problems and limitations when applying the principle in practice. We conclude that there is a whole series of complications that may occur, including non-marginal projects that affect permit prices, permit markets that are far from transparent, several different instruments that capture different aspects of a $CO_2$-value, multiple policies present simultaneously to name a few discussed above.

One main conclusion from this second part of the paper is that it is difficult to establish $CO_2$-value to apply in CBA:s for infrastructure projects. However, this should not be taken as a reason to abandon the shadow price approach in favour of a social cost of carbon approach. The principles put forward are still relevant, even if they are hard to apply. Furthermore, it is worth noting that to a large extent the difficulties in applying a shadow price approach lie in the complexity and variation of the policies adopted.

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