

Climate Policy to Defeat the Green Paradox

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Abstract Carbon dioxide emissions have accelerated since the signing of the Kyoto Protocol. This discouraging development may partly be blamed on accelerating world growth and on lags in policy instruments. However, it also raises serious question concerning whether policies to reduce CO₂ emissions are as effective as generally assumed. In recent years, a considerable number of studies have identified various feedback mechanisms of climate policies that often erode, and occasionally reinforce, their effectiveness. These studies generally focus on a few feedback mechanisms at a time, without capturing the entire effect. Partial accounting of policy feedbacks is common in many climate scenarios. The IPCC, for example, only accounts for direct leakage and rebound effects. This article attempts to map the aggregate effects of different types of climate policy feedback mechanisms in a cohesive framework. Controlling feedback effects is essential if the policy measures are to make any difference on a global level. A general conclusion is that aggregate policy feedback mechanisms tend to make current climate policies much less effective than is generally assumed. In fact, various policy measures involve a definite risk of ‘backfiring’ and actually increasing CO₂ emissions. This risk is particularly pronounced once effects of climate policies on the pace of innovation in climate technology are considered. To stand any chance of controlling carbon emissions, it is imperative that feedback mechanisms are integrated into emission scenarios, targets for emission reduction and implementation of climate policy. In many cases, this will reduce the scope for subsidies to renewable energy sources, but increase the scope for other measures such as schemes to return carbon dioxide to the ground and to mitigate emissions of greenhouse gases from wetlands and oceans. A framework that incorporates policy feedback effects necessitates rethinking the design of the national

and regional emission targets. This leads us to a new way of formulating emission targets that include feedback effects, *the global impact target*. Once the full climate policy feedback mechanisms are accounted for, there are probably only three main routes in climate policy that stand a chance of mitigating global warming: (a) returning carbon to the ground, (b) technological leaps in zero-emission energy technology that make it profitable to leave much carbon in the ground even in Annex II countries and (c) international agreements that make it more profitable to leave carbon in the ground or in forests.

Keywords Rebound effect · Green paradox · Climate policy

THE CLIMATE POLICY ILLUSION

Since the signing of the Kyoto Protocol, CO₂ emissions have accelerated from 1.3% per year in the 1990s to a staggering 3.3% per year from 2000 to 2006. This trajectory has propelled the atmosphere into some of the worse scenarios in the IPCC’s 4th Assessment Report scenarios. An optimistic view is that emissions temporarily accelerated due to the surge in world economic growth in the years 2003–2007 and lags in policy implementation. In 2009, for example, emissions will probably temporarily fall in the economic downturn. A more pessimistic view is instead that post-Kyoto emissions would have accelerated even more if it had not been for a one-time shift in the industrial structure of many former communist countries. Lower emissions in many eastern European countries are the main reason why Europe stands a chance of reaching its Kyoto targets (Fig. 1).

The UNFCCC negotiations are grounded on the assumptions that: (a) it is possible to stay within the 2°C

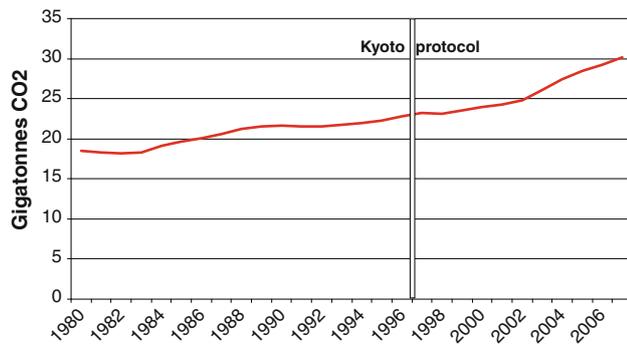


Fig. 1 World carbon dioxide emissions from fossil fuels before and after the Kyoto protocol was signed

target with a global reduction target of 50% by 2050; (b) the 2°C target is sufficient to avoid ‘dangerous climate change’; (c) we are not yet in a danger zone today, in terms of GHG concentration levels; (d) current climate policies are by and large effective and simply need to be scaled up.

Worryingly, many of these assumptions may be too optimistic. This article takes issue with the fourth assumptions. Negotiations as well as most countries’ climate policy design may start from an outdated or misleading view of the effectiveness of many measures to reduce emissions. This would greatly hinder, or at least delay, the world’s chances of mitigating global warming.

One reason for the neglect of climate policy failure is that many studies of so-called carbon leakage and rebound focus on partial and short-term effects, and thus convey a misleadingly sanguine impression.

For example, extraction and burning of harvest residue from forests is often assumed to be renewable and, therefore, free of CO₂ emissions when climate policies are designed. This assumption ignores that extraction and transporting gives rise to emissions, and that burning the residue releases carbon dioxide 10–30 years earlier than otherwise would be the case. If the substituted fossil fuel then is available on the world market and used elsewhere, the net effect of residue burning may actually be an increase in CO₂ emissions.

The following article is an attempt to conceptualise the aggregate of various feedback effects into one coherent model.

A CONCEPTUAL FRAMEWORK FOR POLICY FEEDBACKS

Many climate policy reports, such as the Stern review (2006), attempt to estimate the theoretical cost of reducing emissions assuming that climate policy is efficient and that all countries, firms and consumers act rationally. If similar reasoning were applied to other human calamities such as

crime, warfare or malnutrition, the conclusion would almost certainly be that the theoretical cost of reducing these is close to zero or negative. Yet they persist. Clearly, the relevant question must instead be which policy instruments are available and how effective they really are, once side effects and feedbacks are accounted for.

A policy measure intended to reduce carbon emissions generally consists of a tax, a subsidy or some regulation. It is not always obvious which is which. For example, a reduced vehicle tax for low-emission cars can be described as a subsidy or as an extra tax on high-emission cars. Similarly, a cap-and-trade system can be described as a regulation, but if emission rights are auctioned off it is much the same as a tax.¹

There are other policy measures that we do not explicitly address in this article. Among them are various ways of creating awareness, and direct government investments or purchases. Even these can give rise to similar feedback mechanisms as are illustrated in this article.

Taxes, subsidies and regulation can be described as having two principal effects. They can (a) reduce the level of carbon emitting activities and/or (b) increase carbon efficiency so that emissions are reduced for a given level of activity. In practice, firms that meet a carbon tax or a cap-and-trade system can react by (a) cutting down production or/and (b) investing in more emission efficient production.

The same reasoning holds for the consumers. A gasoline tax could (a) reduce traffic and communication and/or (b) make people invest in more carbon efficient ways of transport such as hybrid cars or public transport.

Correcting the market failure of carbon emissions can be motivated in terms of social costs and benefits. In order to do this correctly, the feedback effects that the policies or correction mechanisms give rise to have to be accounted for. These are often described in terms of leakage and rebound. Unfortunately, there are no commonly agreed definitions of these terms. Empirical studies on leakage, for example, often include some rebound effects and vice versa. For the purpose of this article, policy feedback mechanisms will be grouped in four categories as shown in Fig. 2: Leakage, local rebound, global rebound and innovation feedbacks.

Feedback effects include *carbon leakage*, the rise of emissions in Annex II countries due to the regulated activity in countries that reduce emissions; *rebound effects*, a lower price of carbon emitting products will give rise to an increased demand that reduces the initial effect; *innovation feedbacks*, a higher price on carbon has positive, dynamic effects on innovation and negative effects on carbon prices.

¹ A real difference in efficiency between the cap-and-trade and a tax system arise when uncertainty is introduced, depending on elasticities. See Weitzman (1974).

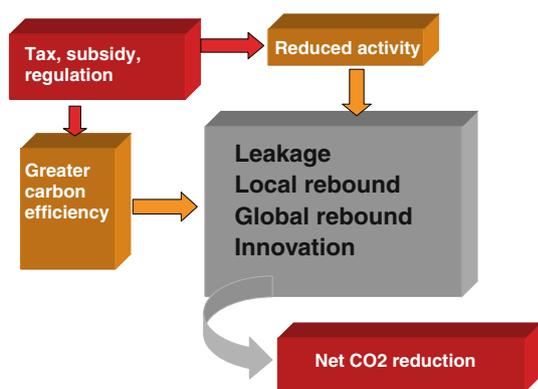


Fig. 2 Feedback effects of taxes, subsidies or regulation to reduce carbon emissions

A feedback effect of 10% means that 10% of the initially intended emission reduction will be lost because of more production outside the area (leakage) or through the increased demand (rebound effect) also taken into account the innovation effect. If the feedback effect is over 100%, then the entire initial reduction is lost and global emissions will actually rise or backfire.

The following section reviews the channels through which the feedback effects work and examples of how the framework can be used.

Carbon Leakage

Leakage has often been analysed narrowly as the short-run effects on sales and production patterns as a result of higher CO₂ emission costs. Table 1 shows different estimates of cost increases in some industries that are affected by the European emission trading system (ETS).

Based on these estimated cost increases, various models are used to calculate the extent of leakage. OECD (2008) estimates that a cost increase of 1% in the industries above leads to reduced production in Europe of 3–4%. This would give rise to leakage of 12.6 by the year 2020 (and 19.9% by 2050 with a 50% emission reduction), but considerably lower if other countries such as China and Brazil join the abatement countries.²

This estimate and others like it are based on large-scale Computable General Equilibrium (CGE) analyses. Based on these, the IPCC (2007) assumes modest leakage rates for the Kyoto Protocol.

Nevertheless, these estimates are based on short-term effects. In the long run, it is conceivable that entire carbon intensive production facilities close down in Europe and are replaced by purchases from other countries. In that

² The EU produces similar estimates, see EC (2008a, b). See also Paltsev (2001), Babiker (2005), Gerlagh and Kuik (2007) and Marschinski et al. (2008).

case, leakage would be considerably larger. From Sweden, for example, paper and pulp facilities shut down at a rate of 2–3% a year, largely replaced by start ups outside Europe.

In addition, there may be considerable leakage from industries that are not heavy CO₂ emitters but comprise a much larger share of the total. For example, vacations abroad are a rapidly expanding way of moving consumption to Annex II countries. An indication of this is given by estimates of the emissions that Europeans give rise to both at home and abroad. Studies put the emissions from Sweden at about 6 tons per inhabitant and year. However, the emissions a Swede gives rise to including via imports and excluding emissions in the production of exports are put at 6.3–12 tons depending on assumptions used. The most ambitious calculations land in the upper range.³ These figures are not necessarily a fair representation of Swedes’ global impact since they ignore emission savings of Swedish firms and technology abroad. However, they are an indication that leakage can be much larger than estimated by models that only take account of some of the high energy-using industries.

Rebound Effects

The rebound effect can be divided into local and global effects. This distinction is fruitful since most empirical papers on the subject only consider local rebound.

An example of local rebound is energy savings that lower the price of energy, allowing consumers to spend more on other goods and also lowering the relative price of energy ending up spending more on both.⁴ Global rebound effects, or macroeconomic effects, prevail when energy savings in, e.g. Europe entails lower energy prices and thus increase demand elsewhere in the world.

Sorrell et al. (2009) provide an overview of the problems in capturing the rebound effect, but stresses the fact that the effect must be taken into consideration and criticise Stern (2006) for neglecting these effects.

Local Rebound

Literature reviews of local rebound effects can be found in Greening et al. (2000), Binswanger (2001) and Dimitropoulos (2007). Many of the studies identify a part of the local rebound effect. For example, studies attempting to estimate first-order effects in the transport sector find rebound effects ranging from 5 to 51%.⁵ Similarly, studies

³ Carlsson-Kanyama et al. (2007).

⁴ This mechanism can be seen in analogy with textbook economics of the substitution and income effects of a price change.

⁵ Examples of such studies are Blair et al. (1984), Leung and Vesenka (1987), Mayo and Mathis (1988), Weinblatt (1989), Gately (1990), Greene (1992), Walker and Wirl (1993), Houghton and Sarker (1996).

Table 1 Increased production costs in European high leakage industries as a result of 20 €/ton CO₂ emission cost

Study	Iron and steel, primary (%)	Iron and steel, secondary (%)	Paper and pulp (%)	Cement (%)	Country	Model
Ho et al. (2008)	4.6	1.4–2.0	2.6–3.2	10.0	USA	Partial equilibrium, fixed proportions of inputs, import substitution, constant technology
IEA (2005) ^a	15.4	3.0	7.2	37.2	EU	Sectorstudy, constant technology, 10% free emission rights
Smale et al. (2006) ^a	11.3	–	24.0	96.0	UK/EU	Cournotcompetition, abatement curves from DERFA, free emission rights
McKinsey (2006)	17.3	2.9	1.0–7.5	36.5	EU	Sectorstudy
CE Delft (2008) ^a	5.8	3.1	0.6–0.8	0–4.3	NL	Sectorstudy, no indirect costs
Climate Strategies (2007)	27.0	2.0	9.0	34.0	UK/EU	Sectorstudy, some technological change

^a Prices expressed as marginal costs

Note: The cost increases are short term increases of production costs at a constant cost of 20 €/ton CO₂-emission

Source: Copenhagen Economics (2009)

of first-order effects of greater energy efficiency in housing produce a range of estimates between 5 and 65%.⁶

The higher figures typically arise in studies that estimate both long-run and short-run effects. A typical example of these studies is an analysis of the fuel economy rebound effect for US household vehicles using data on US households' consumption of car transport.⁷ The conclusion is that the long-run first-order effects amount to 20% of the initial fuel saving.

Estimates of first-order effects in industry range from 0 to over 100%.⁸ In addition to the first-order effects, the second order and economy-wide effects have to be considered. A number of studies find that these effects roughly double the first-order effects. For example, a study of a number of British energy conserving policies found the economy-wide rebound to be 11%, on top of first-order rebound effects of 15%. However, another study of the same policies put the total of first-order and economy-wide effects at 40%.⁹ Roy (2000) finds a rebound effect of more than 50% due to the income effect of greater energy efficiency in Indian households. Frondel et al. (2007) find rebound effects between 57 and 67% analysing fuel efficiency improvements in a panel of German households.

In many cases, the studies cited focus on more easily quantifiable aspects and ignore those that are more difficult to measure or simulate. That this can make a big difference is illustrated by Brännlund et al. (2007) who simulate

first- and second-order rebound effects when interactions between the Swedish transport and heating sector are taken account of. The result was that initial energy saving of 20% eventually led to increased carbon emissions of 5%. This is a rebound effect of over 100%, which often is termed 'backfire'.¹⁰ In CGE models that are designed to capture the economy-wide rebound effects backfire is frequently found, e.g. Glomsrod and Taojuan (2005) for the case of energy efficiency improvements in China or Hanley et al. (2008) for energy efficiency improvements in Scotland.

Studies that have come close to capture the rebound effect over time include Schurr (1985) and Fouquet and Pearson (2006), which provides long time series of energy usage and conclude that there are backfiring effects.

The risk of backfire is particularly prevalent in the light of European carbon dioxide emission limits. For example, subsidies to railroads expansion are often motivated by climate considerations.¹¹ The key question, however, is how additional railroad traffic affects global carbon dioxide emissions. Since Europe has agreed upon overall limit for carbon emissions, the main effect of additional railroads is merely to move emissions from the non-tradable (transport) sector to the tradable (coal-fired electricity generation) sector.

Even if Sweden tightened its national targets in connection with railroad investments, the net effects' risk

⁶ Examples of studies are Khazzoom (1986), Dubin et al. (1986), Dinan (1987), Hirst (1987).

⁷ Greene et al. (1999).

⁸ Examples are Bentzen (2004), Greening et al. (2000), Laitner (2000), Saunders (2008).

⁹ Allan et al. (2007) and Turner (2009).

¹⁰ See also Mizobuchi (2008) who argues that the rebound effect can be smaller if capital costs are large since the income effect is reduced.

¹¹ In Sweden, railroads used 1.4% of Sweden's electricity consumption in 2006, but 34% of Sweden's import of electricity which mostly came from Danish coal fired plants (SIKA 2007; Svensk Energi 2008).

being negligible, since the European limits are unchanged. The Swedish investment would raise electricity prices and prices for emissions rights and thus discourage similar investments in other countries. Thus, subsidies to railroads in European countries may have negligible net effects on carbon dioxide emissions and may in fact backfire once the global rebound effects, discussed below, are taken into consideration.

Global Rebound

Local rebound has received much attention, partly because climate policies are often designed with an eye to national emission reduction targets. In order to prevent global warming, the effects on global emissions are the only relevant measure. Global rebound arises when energy savings in some countries reduce energy prices on the world market and in Annex II countries, leading to an increased global demand.¹²

In a recent study, Terry Barker, of the Cambridge Centre for Climate Change Mitigation Research, examines the world-wide rebound effects of the International Energy Agency’s (IEA) recommendations for efficiency measures. He concludes that if they are followed in the next few decades, the total rebound effect—the proportion of potential energy savings offset by changes in consumer and industry behaviour—could be 31% by 2020 and about 52% around the world by 2030.¹³

Initial simulations of short-term global rebound effects put these at smaller values largely because coal supply is assumed to be rather elastic in the short run. Thus, climate policy measures that reduce demand in the short run would seem to imply a significant reduction in carbon extraction. These short-run effects are sometimes included in estimates of leakage discussed above.

In the longer run, however, demand rises toward a zone where supply is much more inelastic because carbons are at the margin extracted in places where extraction is increasingly expensive. This means that the short-run effects of climate policy may have little effect on the long-run emissions of carbon dioxide.

Figure 3 illustrates this. The supply curve depicts the costs of extracting carbon over the entire range of remaining fossil carbon reserves. The demand curves refer to aggregate demand (not annual) over the short and long term.

In recent years, research literature has evolved that explicitly takes account of how energy savings in some countries interact with the supply strategies of countries

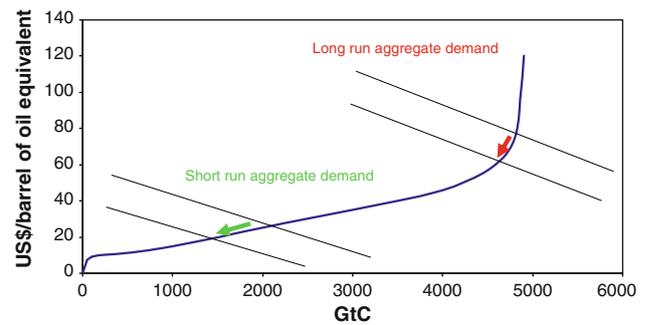


Fig. 3 Aggregate carbon supply curve and demand in the long and short run. *Note:* This figure is merely illustrative. A more detailed analysis should take account of the fact that the curves look quite different for oil, gas and coal. Estimates of remaining supplies and cost curves also vary wildly. See, for example, Rutledge (2007)

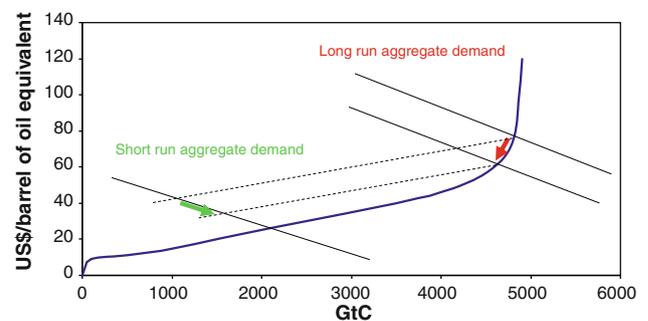


Fig. 4 How lower long run demand of carbon can increase short run supply

that extract fossil energy.¹⁴ A disturbing conclusion is that energy savings in some countries have a small, or even reverse, effect on carbon supply even in the short term.

The issue can easily be understood in terms of the figure above. Higher long-run demand leads carbon extracting countries to expect higher future prices. It is then better to leave more oil and coal in the ground and slow the rate of extraction. If the effect of greener policies is to lower long-run demand, then it may be better to increase the rate of extraction.

In Fig. 4, the dotted lines show what short-term price carbon suppliers will demand given a discount rate and an expectation of long run price. Figure 4 illustrates that if long run expected demand falls, the short-run supply of carbon can very well increase.¹⁵

¹² Wei (2009) analyses a general equilibrium model of global rebound effects.

¹³ Barker et al. (2009).

¹⁴ Sinn (2007, 2008). An early study that pointed to this effect was Felder and Rutherford (1993). Additional studies in this direction are Hoel and Kverndokk (1996), Rubio and Esriche (2001).

¹⁵ While some oil producers may not be as far sighted as this reasoning implies, others, such as Saudi-Arabia, Kuwait and Mexico clearly pump much less oil in the short run than they could, and explicitly refer to long run price expectations.

Eichner and Pethig (2009) show in a theoretical model how this interaction leads to considerably higher global rebound effects under a wide range of reasonable assumptions and in some circumstances even can exceed 100%.

One might think that if most countries eventually sign future abatement agreements, then global consumption of fossil energy should fall significantly. This is, however, not necessarily the case. Some 30% of all countries have fossil energy and may be reluctant to leave it in the ground. Sweden exploits its peat and Canada its oil sands. What, then, are the chances that Iran, Venezuela and Turkmenistan are going to curtail oil production? Many of the poorer oil-producing countries also have rapidly rising living standards will eventually be able to use all the oil that richer countries from. This point was starkly apparent in the years 2004–2007 when increased oil consumption in the Middle Eastern countries equalled about half of the global increase in oil production.

Innovation Feedbacks

Climate policies stimulate technological improvements of energy efficiency or non-fossil energy production. These in turn can give rise to both negative and positive feedback mechanisms. The main negative feedback is a straightforward extension of the global rebound effect discussed above.

Figure 5 depicts a ‘green technology supply curve’. The higher the price of carbon fuels, the more profitable green technology is and the more will be supplied (here measured in terms of carbon fuels that are not extracted in the long run). Figure 5 also depicts a fossil fuel demand curve showing that the more green technology promises to replace carbon fuels, the more carbon prices fall, which erases some of the stimulus provided by climate policies. Thus, the net effect of

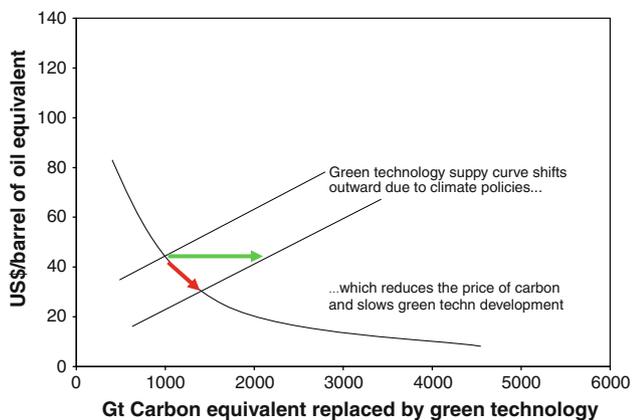


Fig. 5 Energy efficient technology lowers oils prices

green technology on carbon supply follows the short red arrow, rather than the long green arrow.

For example, Popp (2006) illustrates this negative feedback mechanism in a macroeconomic model, also capturing R&D subsidies pooling researchers into one type of technology at the expense of others. He concludes that subsidies to green technology will not reduced carbon emissions that much unless they are complemented by a carbon tax to counteract the effect of falling oil prices.

Since a carbon tax will not be applied in Annex II countries, the adaption of green technology in these countries is not straightforward. The technological advances must be so dramatic that they allow Annex II countries to produce zero-emission energy at a cost lower than the marginal cost of extracting fossil fuels.

The possible positive feedback of climate policies in a dynamic setting are that they can stimulate further technological innovation leading to lower emissions later on. The concept of positive external effects of technological development on future technological advance is well established and part of the motivation for tax-financed R&D.

A stronger version of the positive technological feedback thesis is that they not only make a big difference in reducing carbon dioxide emissions, but actually stimulate economic growth. This so-called Porter hypothesis builds much on the idea of a first-mover advantage, which per definition cannot exist for the world as a whole. Even for individual countries, there is little empirical support for the Porter hypothesis.¹⁶

Within the EU green technology is primarily supported through ETAP (Environmental Technologies Action Plan). ETAP is a way to assemble the member states' different efforts to find synergy effects within Europe. The action plan is not binding but it implicitly puts pressure on the member states to take action, and all countries are required to report national action plans in promoting green technology. For instance, the Swedish action plan concludes that Sweden need ‘to develop special tailor-made and system oriented action packages in order to raise the market share of environmental technology’.¹⁷ The Danish action plan is even more specific and concludes that wind power, biomass, aquatic environment and energy efficiency are the prospering markets in Denmark.¹⁸ In the latest ETAP review from the EU commission, it was concluded that further stimuli are needed to promote the diffusion of green technology.¹⁹ Instruments like standards, definitions of focus areas and subsidies are advocated. The fact that the

¹⁶ Brännlund (2007).

¹⁷ Swentech (2007, p. 70).

¹⁸ Danish Environmental Protection Agency (2007).

¹⁹ EC (2007).

state aids are allowed for green technology and that member states are required to report their efforts induces politicians to act.²⁰

Many of these targeted initiatives create some negative feedbacks apart from the positive, intended effect. A recent example is the EU-regulation on car emissions which is set 130 g CO₂ per km for new cars. Regulations always run the risk of excluding new techniques from the market, since they often are forced to be expressed in technical or unclear terms. An example of this is how the regulation will handle undergoing research at Georgia Institute of Technology, where the car emissions are collected directly from the exhaust pipe. The collected emissions are later disposed at the service station and transformed into fuel.²¹ The EU-regulation does not define whether such techniques are in compliance. Such uncertainties discourage at least some innovations. Regulations should therefore aim to be technologically neutral but this is always complicated.

This is just one example of when political interventions in the market create uncertainty. Targeted sectors, standards and subsidies are often not stable and therefore not credible. Experience with attempts to ‘pick winners’ among future technologies has, in general, not been encouraging. This appears to be true also for green technology. Evidence presented in Fig. 6 does not obviously support the strategy taken by the EU. Data for EU-27 indicate that targeted subsidies do not entail large exports of green technology.

According to some rankings, the US has the most developed green tech market.²² A large amount of private capital invested is a boon to commercialising green products.²³ Commercialisation is often identified as the main bottleneck for European green tech growth (Fig. 7).

One problem appears to be that selective measures to stimulate green technology often lack predictability and continuity which unnecessarily raise risks for private investors.²⁴

The abundance of policy instruments such as different kinds of targeted taxes, subsidies and standards both nationally and on the EU level create uncertainty and reduce the supply of private capital. This notion runs the risk of creating a downward spiral, where a more activist targeted policy ends up with less private investments in green tech.

²⁰ EC (2001).

²¹ Damm and Fedorov (2008).

²² ITPS (2008).

²³ Lindström and Olofsson (1998), Gompers and Lerner (2001), Hellman and Puri (2002) and Bottazzi et al. (2004).

²⁴ Dealflower (2003) and Nutek (2007).

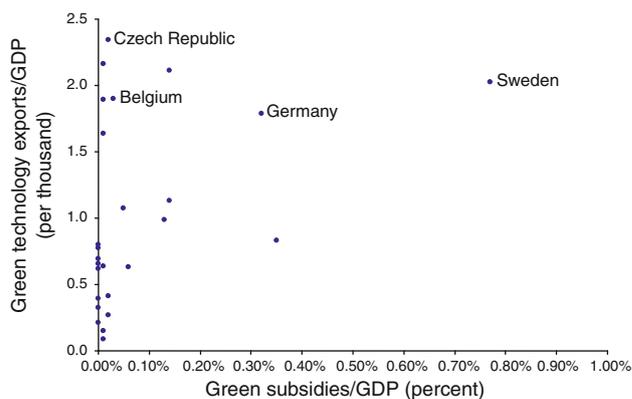


Fig. 6 Green subsidies/GDP and export of greentech/GDP per mille, average 04–06. *Source:* Eurostat and DG Competition

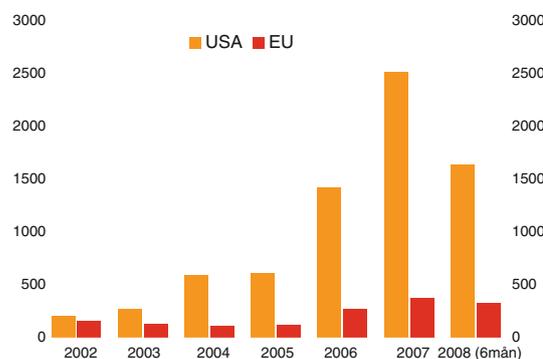


Fig. 7 Private equity in greentech in million USD. *Source:* Ernst and Young (2008)

How Feedback Effects Add Up

The following section illustrates more specifically how the policy feedback framework can be used. The main conclusion from the empirical work on estimating the feedback effect is that it is very hard to capture the entire effect. There are many variables that are interdependent, which are hard to separate and control for. Sorrell et al. (2009) provides an overview of the problems in capturing the rebound effect, but stresses the fact that these effects must be taken into consideration and criticise Stern (2006) for neglecting these effects.

A Unilateral European Emission Target

The EU has set up a very ambitious target to reduce emission with 20% by the year 2020. However, in designing this target, not much attention has been paid to the feedback mechanisms that will contradict the ambition of reducing emissions on a global level.

Carbon Leakage Policy instruments as the EU-ETS and national carbon taxes have negative side effects on the

competitiveness of European enterprises. The reason is that European companies will meet higher energy prices and costs for carbon emissions that their competitors outside Europe will not face. European industries facing global competition will sometimes be forced to reallocate production outside Europe. Both these mechanisms entail an acceleration of carbon emissions in the non-regulated regions outside Europe.

Local Feedback An important component in meeting the European target for a 20% reduction of emissions until 2020 is energy efficiency. This is a relatively cheap way of reducing direct emissions, but not necessarily global emissions. The EU has an independent target of improving energy efficiency by 20% within EU. The target entails policy instruments specifically directed for energy efficiency, which regularly clash with policies for reducing CO₂ emissions and the renewables target.²⁵ Since the problem concerns emissions of carbon, political interference in the means to an end often creates more problems than solutions.

Assuming that the energy efficiency target will be met, energy prices in Europe will be held down. This will lead to a substitution and income effect. The reduction in price will also give the consumer more money to spend on other things, perhaps imported products from non-regulated countries with production that increases global emissions. Both these effects make up the *local rebound effect*. These effects most definitely exist but the empirical studies of the local rebound effects have a very large spread and are rarely capture aggregates.

Global Feedback Europe is an important actor on the world market. European demand is not an insignificant part of the aggregated world demand and actions are taken to reduce demand for fossil fuel. Lower European demand for oil has a negative effect on the world price of oil, making it cheaper for other countries to consume. If Europe is credible in this strategy, the oil-producing countries will, according to Sinn's Green Paradox, be provided with an incentive to pump up the oil faster as the future price will go down due to a lack of demand.²⁶

Empirical data from the US and different European countries show a rebound effect in the transport sector around 30%.²⁷ The studies, however, do not capture Sinn's

Green Paradox since they do not take account of how a regional reduction in demand also has an effect on the global price, i.e. supply and demand outside the regulated region. If this is included Sinn argues that the European efforts can backfire, i.e. the rebound effect will exceed 100%. In the example below, we assume that the global rebound effect.

Innovation The hardest feedback mechanism to quantify is the innovation effect, partly because of the long time lags involved in developing technology caused by a higher price of carbon. Evidence for the causality between a high price of carbon and the development of green technology is pretty weak or can be explained by a very long time lag. The EU, and Sweden in particular, has, for a long time, been very adamant in regulating emissions with taxes and later the cap-and-trade system, EU-ETS. Despite this, the US is by far the most successful actor on greentech market without much carbon regulations.

Summing Up the Effects There is a complex relationship between the feedback mechanisms. In Fig. 8, we illustrate how they can be aggregated in a stylised manner, for the case of unilateral European target.

In order to capture the whole feedback, the four types of feedbacks can be considered cumulatively, assuming that global rebound applies to emission reductions that are not lost due to leakage and local rebound. In this simplified example 59–100% of the initial 20% reduction within Europe will be lost due to feedback effects. The total feedback effect for the unilateral European emission target may thus be much smaller than commonly assumed.

Political Focus on Biofuel

Like all theory, the feedback model gets more accurate with more detailed examples. In combination with reducing oil consumption in Europe, a lot of focus has been put on promoting biofuels, especially in Sweden.²⁸ The crucial point there is that the production of biofuels or biomass itself gives rise to carbon dioxide emissions. In many studies, these emissions have been quantified at a magnitude of 30–70% of corresponding amount of fossil fuel. A number of recent studies, however, arrive at much higher estimates. For example, a recent report from the International Council for Science (ICSU) concludes that the production of biofuels actually releases more greenhouse gases than a corresponding amount of fossil fuel. The reason is that production

²⁵ A general equilibrium model of the Nordic energy market shows that there the energy efficiency target is in conflict with introducing many of the renewable energy sources on the Nordic market (Profu 2008).

²⁶ Sinn (2008).

²⁷ See, e.g. Anson and Turner (2009) and Binswanger (2001).

²⁸ Kågesson (2009).

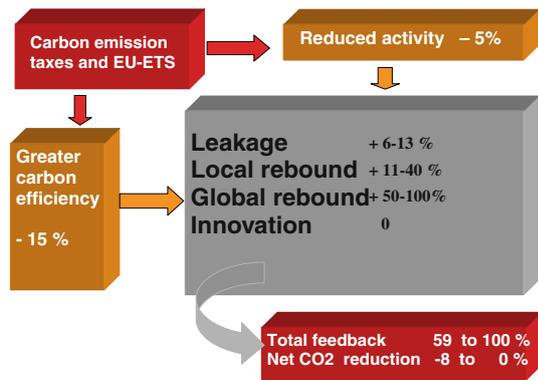


Fig. 8 How do feedbacks sum up? Example 1: A unilateral European emission target enforced by carbon taxes and ETS. *Note:* The figures are based on the empirical studies in “A conceptual framework for policy feedbacks” section

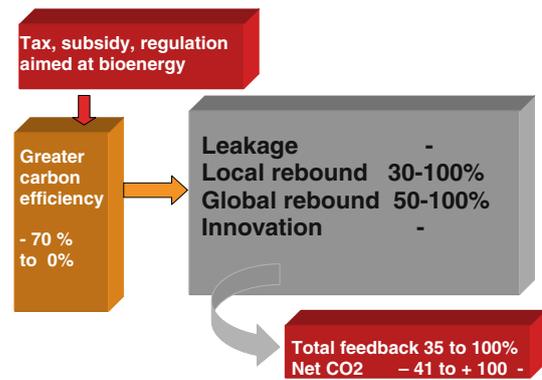


Fig. 9 How do feedbacks sum up? Example 2: Subsidies to bioenergy

of many biofuels releases nitrous oxide (N₂O) which is a much more potent greenhouse gas than carbon dioxide.²⁹ Therefore, it might be more reasonable to put the local rebound effect from bioenergy in the range 30–100% of a corresponding amount of fossil fuel.

The problem is that the saved fossil fuel is not left in the ground just because extra biofuel is produced. If the saved fossil fuel is subject to the global rebound of 50–100%, then the net greenhouse gas emissions somewhere in the range of a decrease of 41% and an increase of 100% (Fig. 9).³⁰

The large spread of the result captures the fact that bioenergy sources differ in efficiency. There is, e.g. a big difference in promoting ethanol in comparison of using leftovers from sawmills for wood pellets regarding the feedback effects.

Apart from not recognising the feedback effects in the renewable target, other claims are often connected to this target. EmployRes (2009) also makes the claim, based on elaborate macroeconomic modelling, that the policies promoting renewable energy systems create more jobs. This claim is, however, based on three rather dubious assumptions. One is that Europe over the coming decades is going to be in a state of unemployment due to insufficient demand that can be alleviated by the investment impetus that renewables provide. The other is that labour intensive biomass really is a part of the policy mix, even though it may actually backfire in terms of CO₂ emissions, and the third is that only jobs count. After all consumers have to pay more for energy and lose real purchasing power.

²⁹ Maize and rapeseed are said to be particularly nitrogen-leaky, but the upshot is that all agricultural production that uses nitrogen-rich fertiliser release nitrous oxide (International Council for Science 2009).

³⁰ Even harvest residue from forests probably increases carbon dioxide emissions during the first 20–40 years. See, e.g. Holmgren et al. (2007).

CLIMATE POLICIES THAT DEFEAT FEEDBACKS

Having gone through the feedback mechanisms, the remaining question is how they can be kept to a minimum under the current climate policy agenda. Climate policies generally focus on national mitigation strategies. Discussion within the EU concentrates on burden sharing between countries and national strategies to cut national emission, without much attention paid to the feedback effects. The framework for taking account of policy feedbacks presented here illustrates how global emission reductions are likely to be much smaller than what could be expected from summing the climate strategies of abatement countries.

There is, therefore, a strong case to be made that current climate policies focusing on national targets are not up to the task of reducing global emissions. Therefore, a new way of setting up national climate policies that recognises policy feedback effects is needed.

Global Impact Targets for Climate Policy

An important step towards recognising leakage and rebound effects would be to include them in the national climate targets. What is needed is a target that includes all emission reductions and feedback effects due to a nation’s climate policy. Within today’s organisational structure, this would be the responsibility of the UNFCCC.

The European countries national emission targets according to the Kyoto process can in principal be described accordingly, with Sweden as an example.³¹

³¹ This do not include sectors within the EU-ETS.

Sweden's emission allowance according to Kyoto
 = 83% (of the emissions from 2005)
 + net buy of AAUs – net savings of AAUs
 – annulment of AAUs.

This measurement does not reveal the real emission from Sweden, since feedback effects are not accounted for. A more appropriate and useful emission target for the Annex 1 countries would be the global impact target

Sweden's global impact target
 = Sweden's emission allowance according to Kyoto
 + $x\%$ of emissions from 2005, which is caused by Sweden outside Annex 1.

Adopting a global impact target would include both domestic emissions and the emissions caused abroad from imported goods and other rebound effects. Trade will expand in a more globalised world, and the issue of emissions from imported goods will increase over time. The global impact target is dependent on good statistical instruments in order for countries to accept them. The current measurements display a large spread in the results.³²

Consequently, an important question for the UNFCCC process in Copenhagen is to get developing countries to start measuring and verifying their emission more rigorously. It may not be reasonable to expect developing countries to attain the same binding targets for emission reduction as Annex 1 countries. However, the verification and reporting of their emission are vital to the process of lowering the global emission and adopting a global impact target.

Further, even local feedback mechanisms need to be counted. Many countries simply classify harvest residue from forests or other 'renewables' as zero-emission energy sources. The European directive aiming at a target of 20 renewable energy productions by the year 2020 did not include a correction factor for ILUC (indirect land use change) and allows renewables that have at least 35% lower life-cycle emissions of greenhouse gases compared to fossil fuels.

A standard for counting everything will presumably have considerable consequences for how local climate policies are chosen and designed.

The global impact target would naturally also provide decision makers with incentives to avoid measures that are positively correlated with feedback effects. The first aim is of course to avoid backfiring effects that actually increase

the net emission but also minimise measures with feedback effects.

By and large this will probably mean that support for various bioenergy projects will be scaled back. A number of other directions in climate policy, outlined below, will probably appear more productive.

Maximising Global Impact

Once the full climate policy feedback mechanisms are accounted for, there are three main routes in climate policy that stand a chance of mitigating global warming: (a) returning carbon into the ground, (b) technological leaps in zero-emission energy technology that make it profitable to leave much carbon in the ground even in Annex II countries and (c) international agreements that make it more profitable to leave carbon in the ground or in forests.

Make it More Profitable to Bury It

Many new techniques are under progress for capturing and storing carbon emission. The most developed CCS technique is the one directly connected to coal plants, but different types of filters and vacuums under development. In order to keep this process going, it is important to include these techniques into the market system for carbon. EU-ETS does include CCS techniques at the moment but will in the future. The real difference can, however, be made in countries like China and India. Therefore, the CCS technique must be included in the CDM and JI mechanisms under the UNFCCC negotiations.

In the UNFCCC negotiations, there are also talks on technical standards to guide investments. There is of course a need to assure the quality and safety of different techniques, which are to be included in the system. However, standards on techniques are often a risky way to go since the officials who set the standard are not the people on the research frontier. Therefore, standards will seldom include the latest technology.

Climate policy mechanisms should certainly not discriminate some of the most promising ways of binding greenhouse gases, such as different methods used in forestry and agriculture, such as non-plough tillage. A further step would be to return carbon to agricultural soil. For example, Fowles (2007) analyses consequences of extracting black (elemental) carbon from biomass, which can be permanently sequestered as mineral geomass and may be relatively advantageous in terms of those risks and uses a high-level quantitative model to compare the approach with the alternative use of biomass to displace fossil fuels. Black carbon has been demonstrated to produce significant benefits when sequestered in agricultural soil, apparently without bad side-effects. Black carbon

³² Carlsson-Kanyama et al. (2007).

sequestration appears to be more efficient in general than energy generation, in terms of atmospheric carbon saved per unit of biomass; an exception is where biomass can efficiently displace coal-fired generation. Black carbon sequestration can reasonably be expected to be relatively quick and cheap to apply due to its short value chain and known technology.

Make it More Profitable to Keep it in the Ground

The most attractive route to keeping more carbon in the ground would be if leaps in alternative energy technology made it unprofitable to extract many current carbon reserves. This would be effective because it would also affect Annex II countries. Therefore, more resources should probably be devoted to basic energy research, which at a world-wide level is still far below levels in the 1970s.

Another rather obvious policy measure is to keep carbons locked in. Many countries could probably achieve greater global emission reduction by stopping extraction of relatively costly fossil fuel such as oil sands or peat, than by subsidies to various renewable projects. If climate policies were informed by global impact targets rather than targets for emissions from within a country's borders, this would become rather obvious.

The same is in principle true for deforestation. Deforestation accounts for around 20% of the world's carbon emissions. A reduction in deforestation is vital for coming to terms with global warming. In order to provide incentives for sustainable forestry in developing countries, deforestation could be included in the market for emission rights. There are, however, considerable practical difficulties in doing so (see, e.g. Angelsen 2008). Also, measures to contain deforestation are themselves subject to rebound effects since they increase pressure to harvest forest elsewhere in the world. Even in respect to preventing deforestation, a move towards global impact targets would be a better guide to climate policy. A practical intermediate step may be to follow the route initiated by Norway which has offered \$1 billion by 2015 which will be paid only to the extent that Brazil is able to demonstrate a reduction in deforestation. For this purpose, Norway will develop its own system for tracking deforestation in addition to Brazil's annual statistics.

International Agreements

The only way to fully avoid feedback effects is for all countries to accept binding targets for their emission. However, it is not plausible to expect the developing world to take on the same burden as the developed countries. This means that the problem of feedback effects will not

disappear. However, in order to cut down global emissions, the process of developing a new climate agreement must focus on minimising feedback effects. The current Kyoto protocol did not pay much attention to feedback effects, which is probably the main reason why emissions have kept on rising.

The most important feature in designing the coming climate agreement in Copenhagen is of course to get as many binding targets as possible. This will give a good starting point for dealing with the feedback effects but with the developing world not taking on binding targets, the problem with carbon leakage and rebound effect will not go away. An important and effective feature in order to minimise the problem is sectoral agreements.

Sectoral agreements are binding targets for all companies within certain sectors. This creates a level playfield for all actors competing with each other on a global market. Apart from the EU, Australia and the US, countries like China, India and Brazil have shown some interest for such a solution within the UNFCCC negotiations leading up to Copenhagen. Sectoral agreements are relevant for global markets such as steel, cement, pulp and refineries. Such an agreement would mean that, e.g. China or India accepts binding targets for their steel industry, which would very much ease the problem of feedback effects within steel production.

A successful international agreement must include elements such as sectoral agreements to minimise the feedback effects. Every element of such agreements that do not consider feedback effects contradicts climate action by creating an illusion of emission abatement.

CONCLUSION

The sum of many countries' climate efforts risks being much smaller than its component parts. An overriding reason is the common neglect of feedbacks that climate policies give rise to. This may seem odd, since the idea of feedbacks in nature is so widely accepted.

This article maps many of the partial empirical studies of various climate policy feedbacks and gives some examples of how they may work at the aggregate level. Many climate policies may have much smaller effects than commonly assumed, and some might actually backfire.

There are probably only three really effective climate policy directions that avoid substantial rebound effects: (a) returning carbon to the ground, (b) technological leaps in zero-emission energy technology that make it profitable to leave much carbon in the ground even in Annex II countries and (c) international agreements that make it more profitable to leave carbon in the ground or in forests.

To stand any chance of controlling carbon emissions, it is imperative to recognise climate policy feedback effects and formulate emission reduction targets that internalise these effects.

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