FORES

Moving ahead

Johan Gars

”For almost all countries, including Sweden, the only way to affect the global greenhouse gas emissions significantly is by trying to influence what other countries are doing.”

FORES Study 2011:3

4Es { Essays on Environmental Economics and Entreprenurship

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Moving ahead
Johan Gars

1st edition

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Design: Kalle Magnusson

Print: Sjuhäradsbygdens Tryckeri AB, Borås 2011

Typefaces: Antenna, Freight text
Paper: Scandia 2000 (cover), Edixion Offset

ISBN: 978-91-978532-7-9

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This publication is part of the FORES initiative "Essays on Environmental Economics and Entrepreneurship" — 4Es. The aim of the initiative is to conduct and publish research on environmental economics with clear policy relevance. The 4Es initiative is made possible through the support of the Tom Hedelius and Jan Wallander Foundation.

FORES, 2011

About the author

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About FORES

FORES—Forum for Reforms, Entrepreneurship and Sustainability—is a think tank that seeks to renew the debate in Sweden with a belief in entrepreneurship and opportunities for people to shape their own lives.

Environment and the market economy, migration, entrepreneurship and civil society, integrity, gender equality, global democratisation and modernisation of welfare—these are some of the issues on which we focus. FORES is an open and independent forum for civil society, academics and policy makers throughout Sweden and Europe. Together with people in Sweden and abroad, we will find solutions to better meet the challenges that globalisation and climate change brings. We function as a link between the civil society, entrepreneurs, policymakers and serious research. FORES produces research papers and books, and organises seminars and debates.

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About the Study

No single state is able to solve the problem of climate change alone – certainly not Sweden, with less than 0.2% of global emissions. Therefore, if the aim of a nation such as Sweden is to reduce global emissions in significant numbers, it is necessary to find ways to influence other countries to reduce their emissions as well. This study aims to investigate the possibilities and risks when moving ahead.

If a country moves ahead on climate policies this is beneficial for the climate and, in some cases, also for the country's economy. The benefits are through technological spillovers, within the country and to other countries, but also as a social and economic example for their countries and to reinforce the credibility of the country in international negotiations. There are costs associated with moving ahead and there is evidence of carbon leakage, production moving to pollution havens. However the empirical evidence also shows that the magnitude of this leakage is insignificant. Moving ahead can be made through carbon pricing but may also be complemented by public support to infrastructure and research support, preferably concentrated in specific areas for maximum effect.

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Foreword

The advantages of moving ahead

The European Union (EU) has repeatedly stated that it needs to take a leading role in the struggle against climate change. One of the arguments within the EU for raising the emissions reduction target for 2020 from 20% to 30% is that the EU needs to show leadership – towards other industrial nations as well as towards its own member states.

Businesses frequently emphasise that it would be very damaging for their competitiveness if Sweden, or the EU, would go further in their ambitions to reduce carbon emissions. We are already ahead of everyone else, runs the argument. They stress the risk of »carbon leakage«, that stricter emissions goals will simply transfer production to markets with laxer climate policies. On the other hand there is the opposite argument, put forward both by clean tech businesses and non-governmental organizations (NGOs), that stricter climate goals will increase profitability in the long run as it will induce new technology that will lead to efficiency improvements. This is often presented as the Porter Hypothesis, after management guru Michael Porter.

With these discussions in mind, FORES asked Johan Gars at the Institute for International Economic Studies (IIES) at Stockholm University to look closer into the literature on the subject and investigate whether there is support in economic science for moving ahead. In particular we wanted to look further than the Porter Hypothesis and look at aspects of technology and growth that Johan Gars has worked with at the IIES. We also wanted to see how the economic literature could inform political science, if ambitious climate policies coupled with economic growth, can act as an institutional example for other economies.

The literature survey gives a balanced alternative narrative to the Porter Hypothesis, where carbon leakage is a real but rather marginal issue according to the empirical evidence. There is some evidence that strict climate legislation can create technological advantages if it puts nations on a path early that others will follow later. Given that climate change is a global phenomenon, the interaction between domestic policies and global developments becomes crucial.

It is obvious that small countries cannot, in isolation, solve the climate crisis. Not even the EU is close to seriously mitigating climate change if it acts alone. Even if the EU reduced its emissions to zero, this would still not be sufficient to save the Earth's inhabitants from a two-degree temperature increase.

If Sweden and the EU are serious about climate change, they must therefore find means of influencing other developed economies. This can be done in different ways: by standing out as a shining example of how to reduce emissions in a cost-efficient way with maintained growth; through the development and subsequent spread of new technology and through leadership in

international negotiations. The European system for trading with emissions rights is a clear example of this, as a model for other future emissions markets around the world. It has also spurred the development of various energy efficiency technologies on the global market.

On the other hand, the Climate Summit in Copenhagen in 2009 demonstrated that EU leadership was not enough to bring the world's major emitters, and superpowers, to a deal. Nevertheless China and the US had to react to EU commitments, and felt obliged to make some kind of agreement, however modest, given expectations. Leadership in climate reductions may not be a guarantee of an international deal, but it is a pre-requisite.

An important issue is to what extent emissions reductions can be achieved by purchasing offsets, emissions reductions in other nations with presumably lower reduction costs. Large-scale offset purchases abroad are frequently put forward as an alternative to domestic reductions by Swedish economists concerned with cost-efficiency. However there is a degree of inconsistency in this argument. If Sweden leads almost exclusively by example, Swedish purchases of offsets are in themselves nearly meaningless on a global scale, they are only relevant as an example to others. But as an example this is rather poor. Needless to say every country cannot buy their emissions reductions somewhere else. Offsets are already an important safety valve in every serious climate strategy in the EU and the US. If offsets were their main strategy, costs for offsets would soon rejoin domestic costs in any case as the world would quickly run out of low-cost projects. When the world looks to individual countries such as Sweden or the EU for leadership, the problem is elsewhere: how to achieve the unavoid-

able domestic emissions reductions in the US, China and others while maintaining short- and medium-term growth. Offsets offer no solution or example in this respect.

We hope that this study will lead to a broader understanding of why it is necessary for Sweden to show political determination and move ahead.

FORES would like to thank Johan Gars for his accurate and important work. In particular we send our thanks to Martina Krüger at Greenpeace and Eva Samakovlis at the Swedish National Institute of Economic Research, who have each read the study closely and written comments found in the end of this publication. In addition, we would like to thank Markus Wråke at the International Energy Agency and Conny Olovsson at IIES, for reading and commenting on earlier drafts.

Martin Ådahl,
Director, FORES
September 2011

Summary in Swedish

Sammanfattning

Inget enskilt land kan ensamt lösa frågan om klimatförändringar – särskilt inte Sverige som står för mindre än 0,2 procent av de globala utsläppen.

Om målet med svensk klimatpolitik är att bidra till att minska de globala utsläppen är det därför nödvändigt att hitta sätt för att påverka andra länder. Det sunda förnuftet säger att man påverkar andra genom att själv agera och föregå med gott exempel. Men det förekommer flera diskussioner kring kostnaderna av att gå före. Är det så att de är för höga jämfört med de politiska fördelarna? Eller är det tvärtom så att en ambitiös klimatpolitik leder till långsiktiga fördelar för industrin genom att den väljer rätt spår innan andra länder följer efter?

Denna studie syftar till att undersöka vilket stöd det finns i den ekonomiska litteraturen för dessa olika argument kring att gå före på miljöområdet.

I en stiliserad ekonomisk modell skulle det endast vara rationellt för ett land att ensamt minska sina utsläpp så länge som kostnaderna för minskningen är lägre än vad landet får ut av att släppa ut växthusgasen vid produktion. Om ett land skulle göra minskningar utöver detta ökar kostnaden för det enskilda landet, samti-

digt som nyttan i form av ett förbättra klimat delas bland samtliga.

I en värld utan ett starkt globalt avtal kommer stater – enligt logiken i fångens dilemma – avstå från ytterligare utsläppsminskningar. Men som denna studie visar saknar dessa modeller flera viktiga infallsvinklar som kan förklara varför det är lönsamt att gå före.

Studien tar sin utgångspunkt i tre troliga sätt på vilka det kan leda till minskade utsläpp att gå före:

- Genom att som positivt exempel visa på möjligheten att minska utsläppen till en rimligt kostnad.
- Utveckla teknologi och policymodeller som möjliggör för att länder att minska sina utsläpp till lägre kostnad.
- Skapa trovärdighet i internationella förhandlingar genom att unilateralt genomföra en offensivare klimatpolitik.

Dessa sätt att påverka andra länder diskuteras i tre olika delar:

1) **Koldioxidläckage**, som är den största risken med att gå före,
2) **teknologin**, såväl hur den kan överföras till andra och i vilken utsträckning inhemsk klimatteknologi kan och borde främjas av att gå före, samt
3) hur det påverkar landets möjlighet att påverka de **internationella förhandlingarna**.

Koldioxidläckage

Koldioxidläckage används för att beskriva ett scenario där en ambitiös klimatpolitik leder till försämrad konkurrenskraft och att produktion därför flyttas till länder med lägre eller inga krav på utsläppsminskningar. I ett sådant scenario skadas inte bara landets ekonomi, utan flera av åtgärderna för att minska den globala klimatförändringen blir meningslösa. Utsläppen byter plats, men fortsätter att påverka klimatet.

Teoretiskt motsägs argumentet att produktionen skulle flytta till länder med mindre utsläppsreglering av att kraven på reglering är större i länder med högre inkomster och utvecklingsnivå (som Sverige). Eftersom detta är faktorer som också gynnar utsläppsintensiv produktion, skulle det snarare leda till mer utsläppsintensiv produktion i länder med hårdare klimatlagstiftning.

Enligt studiens empiriska exempel finns det en tydlig risk för koldioxidläckage när man går före. Men mängden utsläpp som flyttar är avsevärt lägre än vad som ofta antas och påverkar bara en liten del av produktionen och utsläppen. Beräkningar från OECD visar att även om EU ensamt minskar sina utsläpp med 50% fram till 2050, så stannar 88,5% av utsläppsminskningarna inom EU. Om samtliga utvecklade länder i det så kallade Annex I skulle göra liknande minskningsåtaganden, är läckaget inte mer än 1,7 % år 2020 och endast 0,7 % år 2050.

Ur ett konkurrensperspektiv visar studier gjorda på det europeiska handelssystemet EU ETS att de sammanlagda effekterna på ett land är litet, eftersom endast en liten del av landets ekonomi påverkas. I Storbritannien bidrar de påverkade sektorerna exempelvis endast till en procent av landets BNP.

En anledning till att risken för koldioxidläckage vanligtvis överskattas är att flera utsläppsintensiva industrier är relativt stationära – produktionen är inte enkel att flytta. Men när risken för koldioxidläckage uppskattas slås den ut över samtliga industrier, inklusive de mer flyttbara med lägre utsläppsintensitet. Risken tenderar då att överdrivas. En ytterligare anledning är att koldioxidläckaget är större till länder med lägre inkomst och svagare klimatreglering, medan handel främst sker mellan länder på liknande utvecklingsnivå och med liknande klimatreglering. Därför bli koldioxidläckaget relativt litet.

Teknologi

En betydelsefull minskning av utsläpp utan att behöva minska produktionen kräver ett teknologiskifte. Den nödvändiga teknologiska utvecklingen är beroende av olika politiska åtgärder som förutsägbar miljölagstiftning, högre pris på utsläpp och direkt statligt stöd till forskning.

Det finns gott om bevis för att miljölagstiftning leder till mer forskning om teknologier som bidrar till att minska kostnaderna för att leva upp till kraven. Att komma åt klimatförändringens externaliteter är i teorin relativt enkelt: sätt ett enhetligt pris på utsläppen av växthusgaser som motsvarar kostnaderna för klimatförändringen. Genom att använda en sådan marknadsmekanism minskas utsläppen på det mest effektiva sättet, eftersom de då sker hos aktörer som har den lägsta kostnaden för att utföra dem. Prissättningen av koldioxid kommer också leda till utvecklingen av ny teknologi.

Beroende på de marknadsmisslyckanden som förknippas med ett teknologiskifte, såsom positiva externaliteter och informationsproblem, krävs emellertid ytterligare politiskt agerande i form av exempelvis infrastruktursatsningar och stöd till forskning för att få till stånd ett teknologiskifte. Dessa åtgärder för dock med sig risker som inlåsningseffekter när besluten om vilken teknik som ska användas överlåts till andra aktörer än de med bäst möjlighet att göra informerade beslut. Därför är det extra viktigt att dessa åtgärder utformas med omsorg, särskilt om målet är att även påverka utsläppen i andra länder.

Privata aktörer kommer alltid att vara större än offentliga när det kommer till användning av och investeringar i teknologi. Som utgångspunkt är det därför centralt att skapa förutsättningar för dessa att investera i grön teknologi, till exempel genom att prissätta utsläpp. Men företag har fortfarande mer att tjäna på att investera i utvecklad fossilbaserad teknik än ny grön teknologi. Under en betydande tidsperiod tenderar privata investeringar därför att riktas mot fossilbaserad teknologi. Således är det nödvändigt med åtgärder som riktas direkt mot forskning, i synnerhet grundforskning.

I studien dras slutsatsen att det troligen är mer effektivt för ett litet land som Sverige att fokusera sina resurser på ett separat, eventuellt smalt, teknologiskt område där man kan göra stora framsteg, snarare än på bredare forskning med mindre chans till betydande resultat. I studien argumenteras också för att från statligt håll skapa en kreativ miljö för basforskning genom särskilda forskningscenter. Det ökar möjligheterna att kunna attrahera privata investeringar för den nödvändiga slututvecklingen av teknologin. Framväxten av sådana forskningscenter gynnas bland

annat av att tillhandahålla nödvändig infrastruktur, provningsanstalter och välutbildad arbetskraft.

Enligt den så kallade Portherhypotesen kan en omsorgsfullt utformad miljölagstiftning bidra till effektivitetsförbättringar som faktiskt gör regleringarna lönsamma. I studien påvisas att det i vissa fall stämmer. Exempelvis kan en striktare reglering stimulera en sektor som tillhandahåller en teknologi som minskar utsläppen. Det kan leda till ökad konkurrens inom sektorn, och bidra till minskade kostnader för teknologin, som i sin tur leder till ökad produktion med mindre utsläpp. Det verkar emellertid finnas en framväxande konsensus att Porterhypotesen inte kan förväntas vara applicerbar på hela ekonomier, då de empiriska bevisen för hypotesens antagande baseras på fallstudier på särskilda sektorer.

Olika typer av spridningseffekter påvisas ofta som positiva bieffekter av teknologisk utveckling. Exempel på detta är när aktörer som inte ännu börjat använda en ny teknologi kan använda sig av – och tjäna på – att utvärdera erfarenheterna från andra som använt teknologin. På liknande sätt kan en ny teknologi som används av flera producenter så småningom innebära att priset för tekniken och produktionen minskar.

En mycket viktig spridningseffekt är när teknik sprids från land till land. Studier visar att teknik som utvecklats i ett land med hårdare reglering kan bidra till att minska utsläppen även i andra länder. Om dessutom avkastningen på forskningen ökar över tid, vilket tenderar att vara fallet, kan ökad satsning på forskning i ett land leda till ökade forskningsanslag även i andra länder. Detta kan i sin tur förklaras av det faktum att forskning och ackumuleringen av kunskap har positiva externaliteter. Forskning i ett land ökar snarare än minskar vinsten av forskning i ett annat. Det innebär

att den så kallade utträngningseffekten inte är något betydande problem.

Ibland ligger de klimatmässiga fördelarna av teknologisk utveckling helt och hållet utanför landet som forskar om och utvecklar teknologin. Ett exempel är Japan, som använt sitt särskilda kunnande till att utveckla solceller för utvinning av el. Japan är inte särskilt väl lämpat för solceller, men landets export av solceller har bidragit till minskade utsläpp i flera andra länder.

Framgångsrik forskning och utveckling kan också ha en positiv inverkad på möjligheterna att nå ett internationellt avtal om betydande utsläppsminskningar, eftersom det minskar kostnaderna för länder att genomföra dem. Det ökar i sin tur viljan att skriva under minskningsåtaganden.

Internationella förhandlingar

Flera av de grundläggande förutsättningarna för hanteringen av klimatförändringarna skapas i mellanstatliga förhandlingar, inom exempelvis regionala eller globala institutioner. Ett internationellt avtal med meningsfulla minskningsåtaganden skulle bidra till att mildra den uppfattade risken för koldioxidläckage. Således kan ett land som konstruktivt lyckas påverka utgången av internationella förhandlingar ha en uppenbar påverkan på de globala utsläppen.

Studien visar att trovärdighet är nödvändigt för att kunna utöva ett effektivt ledarskap i internationella miljöförhandlingar. Trovärdighet uppnås huvudsakligen genom att uppfylla sina meningsfulla minskningsåtaganden genom inhemska politiska åtgärder och bevisa att utsläppsminskningar är möjliga till en rimlig kostnad och med bibehållen tillväxt. Omvänt kan trovärdig-

heten skadas om stora delar av ett lands utsläppsminskningar görs genom köp av utsläppsminskningar utomlands.

Slutsatser

Om ett land går före med sin klimatpolitik gynnar detta klimatet, men i vissa fall även den inhemska ekonomin. Fördelarna skapas genom teknologisk spridning, inom landet och till andra länder, men också genom att framstå som föredöme för andra länder och därmed förstärka landets trovärdighet i de internationella förhandlingarna. Att gå före förknippas också med kostnader och det finns bevis för att utsläpp genom koldioxidläckage då flyttar till andra länder. Men den empiriska bevisningen ger vid handen att mängden koldioxid som läcker är i det närmaste obetydlig. Gå före kan ske genom prissättning på koldioxid, men kan också behöva kompletteras med offentligt stöd till infrastruktur och forskning, som för maximal effekt med fördel koncentreras till några få områden.

Chapter 1

Executive Summary

No single state is able to solve the problem of climate change alone – certainly not Sweden, with less than 0.2% of global emissions. Therefore, if the aim of Sweden's climate policy is to reduce global emissions in significant numbers, it is necessary to find ways to influence other countries to reduce their emissions as well. Common sense would support moving ahead as a means of influencing others. However there are arguments as to the costs of moving ahead; if they are excessively high compared to the political benefits or, to the contrary, a more ambitious climate policy brings long-term benefits for businesses putting them into the correct trajectory early on, before other nations follow suit.

This study aims to explore what support can be found in the economic literature for these different arguments.

In a stylised economic model, the case for moving ahead is weak. It assumes that it is only rational for countries to unilaterally reduce emissions as long as the costs of reductions are lower than their own valuation of the reduction. Should a country make reductions beyond this, the cost would increase for the specific country while everyone will share the gain from the reduction in the form of an improved climate.

In a world without a strong global agreement, states will – according to the logic of the »prisoner's dilemma« – abstain from further emission reductions. But as this study shows, these models fail to include several important aspects as to why it might be beneficial to move ahead.

The study takes three likely ways in which moving ahead can lead to reduced global emissions as a starting point:

1) by setting an example illustrating that it is possible to reduce emissions at a reasonable cost;
2) by developing technology and policy models that allow other countries to reduce their emissions at a lower cost; and
3) by gaining credibility in international negotiations by unilaterally implementing a more stringent policy.

These ways to influence other countries are discussed in three different sections, all related to the effects of moving ahead:

1) **carbon leakage**, the main risk with moving ahead;
2) aspects on **technology**, both how it may be transferred to others and to what degree domestic climate technology can and should be fostered by moving ahead; and
3) the role of moving ahead for **international negotiations**.

Carbon leakage

Carbon leakage refers to a scenario where strict climate policies lead to a loss of competitiveness and where production then moves abroad, to so-called pollution havens. Not only would this hurt a country's economy, it would also mean that many of the measures to reduce emissions to improve the global climate would prove meaningless. The emissions change location, but continue to affect the climate.

The argument that production would move to a pollution haven is contradicted by the argument that the demand for stricter environmental regulation comes with higher incomes and a higher level of development, such as has been the case in Sweden. Since these are factors that also favour emission-intensive production, this would lead to more emission-intensive production in countries with stricter environmental regulation.

According to empirical studies covered by this study there is a significant risk of carbon leakage when moving ahead, but the quantitative effect on emissions is smaller than expected, only affecting a small fraction of production and emissions. OECD estimates show that even in cases where the EU would unilaterally reduce its emissions by 50% by 2050, 88.5% of the green house gas emission reductions would stay within the EU. If the developed countries in Annex I would commit to the same reductions, the leakage of emissions would be as small as 1.7% for 2020, and only 0.7% for 2050. Other studies with a narrower scope confirm effects of the same order of magnitude.

From a competitiveness point of view, studies on the EU'S Emissions Trading Scheme (ETS) show that the aggregate effects

on countries are small, due to the fact that only a small share of the economy is affected. In the case of the UK, the affected sectors contribute only 1% of the country's GDP.

One reason why the risk for carbon leakage is often overestimated in advance, compared to the actual leakage, is that more polluting industries tend to be less mobile. When the risk is averaged over different industries, also less emitting but more mobile, this tends to lead to an overestimation of the risk for carbon leakage compared to the actual result. Another reason for this overestimation is that the risk of carbon leakage is bigger with countries with lower income and less strict regulation. However, since trade largely takes place between countries with the same level of development, and usually also similar environmental regulations, the carbon leakage is relatively small.

Technology

A significant reduction in emissions without a reduction in output requires a significant technological shift. This technological development is dependent on different political measures, such as predictable environmental regulation, a higher price on emissions and direct government support for research.

There is a wealth of evidence that environmental regulation leads to increased research on technologies reducing the costs of complying with the regulation. Addressing the externalities of climate change is relatively simple – put a price on all emissions of greenhouse gas uniformly, equalling costs caused by the externalities. By using such a market-based mechanism, the reduction is achieved in an efficient way, since the actors with the lowest costs

will perform them. The pricing of emissions will also lead to the development of new technology.

However because of the market failures connected to technological change such as positive externalities and informational problems, further policy intervention such as large infrastructure investments and direct support for research is needed. These policy interventions are linked to risks of lock-in effects and leaving the decision-making to others than the best-informed parties, making it crucial to design these policies carefully, particularly if the aim is to have an impact on other countries as well.

Private businesses will always dominate the public sector in terms of use of, and investment in, technology. Thus a starting point is to create the necessary incentives for private businesses to invest in research on new green technology. One way of doing so is to put a price on emissions, but firms can benefit much more from past research if they invest in the more mature dirty technology (meaning fossil fuel-based), rather than new green technology. For a considerable period of time private investments will have a tendency to be disproportionately (in relation to prices of clean and dirty technology) directed towards dirty technology. Hence, a policy aimed directly at the research process is needed, preferably towards pre-commercial research.

The study concludes that it is probably more efficient for a smaller country such as Sweden to focus its resources in a specific, perhaps narrow, technological field where it can make an impact, a giant leap, rather than on a broader research topic with more modest progress. The study argues that it would be wise for the public sector to focus its investments on creating a creative environment for basic research with specific centres of expertise, to

attract the private investments needed to finance the final development of new technology. This can be done through providing the required infrastructure, testing grounds for technology and properly educated labour.

According to the so-called Porter Hypothesis carefully formulated environmental regulations can trigger efficiency improvements that actually make the strict regulations profitable. This study points to evidence that this might happen in some cases. For example, more stringent regulations can stimulate a sector that supplies abatement technology. This could in turn lead to increased competition within the sector, lowering the prices of abatement technology, leading to increased final good production (although not necessarily lower abatement costs). However, there seems to be an emerging consensus that the Porter Hypothesis cannot be expected to be accurate for entire economies, since the evidence of its validity is based on case studies only.

Different types of spillover effects are generally used as examples of positive side effects from technological change. The »learning-by-using« example refers to actors that have not yet adopted the new technology, but can benefit from observing the experience of those that have. The »learning-by-doing« example illustrates that if the new technology spills over so that more producers use it, the production costs typically decrease.

A very important aspect is the technological spillover from one country to another. Studies show that the technology developed in a country with stricter regulation may help to reduce emissions in other countries. Studies also show that if the return for research increases over time, which tends to be the case, research spending in one country could encourage more spending in other countries.

This in turn can be partly explained by the fact that research and the accumulation of knowledge has positive externalities, that is research in one country increases rather than decreases the advancements and benefits from research in another. This also implies that the so-called crowding out, meaning that increased investments in one country lead to less research in another, is not a significant problem.

Sometimes the benefits from technological development are mainly or wholly outside the country that encourages such research and development. One example in a study is Japan, which has used its know-how to develop solar cells for electricity generation (photovoltaic technology). Japan is itself not the best suited country for solar cells, but its export will help several other countries to reduce their emissions.

Successful research and development of new technology may also have a positive impact on the possibilities of reaching an agreement between countries on significant emission reductions, since it reduces the costs of emission reductions, and therefore increases states' willingness to commit to emission reduction commitments in an agreement.

International negotiations

Many of the basic conditions for dealing with climate change are set in inter-state negotiations, be it within the EU or in global institutions. An international agreement with meaningful reduction commitments could reduce the perceived risks of carbon leakage and set a price on emissions, providing long-term incentives for technological investments. Hence, a country able to influence the

international negotiations in a constructive way can have a significant effect on global greenhouse gas emissions.

Sweden and other minor industrialised nations have proven to be instrumental in several international negotiations on environmental issues, through directional and idea-based leadership. The study shows that credibility is imperative to be able to exercise effective leadership. This is primarily done by living up to commitments through domestic measures, setting relevant emission reductions targets, and showing that emission reductions are possible at a reasonable cost with maintained growth.

According to the literature, it is reasonable to believe that the credibility, and therefore the ability to lead, decreases if a large part of emission reductions are done through the purchase of emission reductions abroad, so-called offsets.

Overall findings

If a country moves ahead on climate policies this is beneficial for the climate and, in some cases, also for the country's economy. The benefits are through technological spillovers, within the country and to other countries, but also as a social and economic example for other countries and reinforcing the credibility of the country in international negotiations. There are costs associated with moving ahead and there is evidence to support carbon leakage, production moving to pollution havens. However the empirical evidence also shows that the magnitude of this leakage is very small. Moving ahead can be made through carbon pricing but may also be complemented by public support to infrastructure and research support, preferably concentrated in specific areas for maximum effect.

2

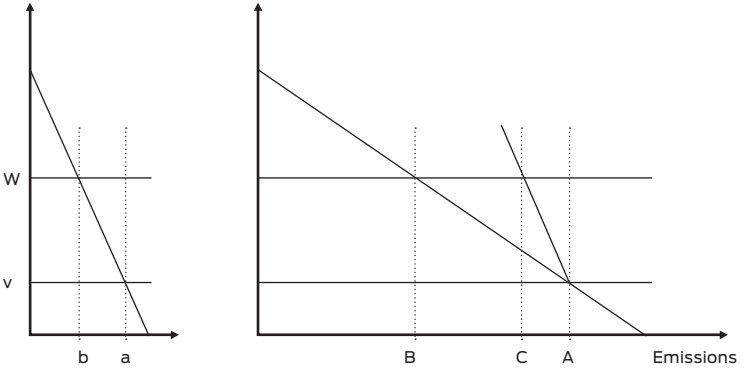
Chapter 2

Introduction

Given the slow progress of international negotiations about reductions in greenhouse gas emissions, there are ongoing discussions about the value of countries moving ahead by conducting a unilateral climate change mitigation policy. The purpose of this document is to provide an overview of what the, primarily economic, research literature says about different relevant issues when discussing moving ahead.

The term 'moving ahead' is often interpreted as adopting more stringent targets, in terms of emission reductions of greenhouse gases, compared to what is prescribed by international agreements, or compared to what other countries are doing. These emission reductions can either be made domestically or through some mechanism where emission reductions in other countries are financed by the country itself. Here, the term will be interpreted more broadly as dedicating more resources to activities aimed at reducing global emissions of greenhouse gases. Note that the discussion in this paper centres primarily on unilateral decisions to spend resources to decrease global emissions. This document does not at all discuss how costs of mitigation policy should be divided among participants within a broader agreement.

Figure 1. Marginal cost and valuation of emission reductions from a national and global perspective.



The diagrams show marginal cost and marginal valuation of reductions of greenhouse gas emissions. The horizontal axis measures emissions while the vertical axis measures cost and valuation of emission reductions.

The left diagram illustrates the perspective of an individual country and the right diagram illustrates the global perspective. In this stylized example, the world consists of three identical countries. If countries choose emissions individually, each country emits the amount a giving total global emissions A. If the countries agree upon the globally efficient amount of emissions, each country should emit b giving global emissions B. If one country makes the globally efficient amount of emissions, b, while the other two countries make the nationally efficient amount of emissions, a, global emissions are given by C.

While this document will explore issues relating to moving ahead with a mitigation policy unilaterally, it is still worth stating that climate change is a global issue, for which an actual solution of the problem requires global action. The preferred path towards a solution is through broad agreements on targets for emissions of greenhouse gases, the tools used to reach those targets, the division of the costs of mitigation, and the division of the costs of climate-related damages.

The diagrams are drawn for a world consisting of three identical countries to make them easier to read. In reality, the differences between one country's valuation of emission reductions and the total global valuation would be much larger. Obviously, the description here is also very much simplified in other respects. In reality, climate change mitigation policy consists of decisions made over a long period of time and under much uncertainty. However, the main points made here hold more generally.

Climate change depends on the concentration of greenhouse gases in the atmosphere, which in turn depends on the total global emission of greenhouse gases. The geographical location of the emissions does not matter. This means that the emissions from a single country have a small effect on the climate, and on the climate change related consequences to which the country is subjected.

Climate change from an economics perspective

Greenhouse gases emissions that cause climate change are typically unwanted side effects of economic activity, e.g. burning of fossil fuels. Since the effects of climate change affect others than those involved in the economic activity, prices will not reflect the total cost of the activity. In economic terms, these effects on others are referred to as 'externalities' and constitute a market failure. It means that prices are no longer correct signals of true social cost and that some kind of intervention is warranted. A stylized illustration of climate change mitigation decisions, on a national and global scale, is shown in Figure 1.

The left-hand diagram illustrates the situation for an individual country, while the right-hand diagram illustrates the global situation. The horizontal lines illustrate the marginal value of emission reductions. The lower lines, v, give one country's valuation of one unit of emission reduction. The higher lines, W, give the total global value of one unit of emission reduction. Since reductions in one country benefit all countries, the total value of one unit of emission reduction in any country is the sum of all coun-

tries' valuation of this reduction. The downward sloping lines give the marginal cost of reducing emissions. The lines are downward sloping because further emission reductions become more expensive as emissions are reduced (which is represented by a movement to the left). The marginal abatement cost line in the right diagram is flatter, since larger reductions can be made at a lower cost if the reductions are divided among the countries, thereby utilizing the potential for relatively cheap reductions in each country before making more costly reductions.

Looking at the left-hand diagram, each individual country would choose to reduce emissions as long as the cost of reduction is lower than their own valuation of the emission reduction, and the country would choose emission level a. The world would then end up at emission level A in the right-hand diagram. From a global perspective, it would be efficient for each country to reduce their emissions to point b, which would put the world at B. If reduction decisions are made by countries uncooperatively, this is a typical example of the Prisoner's Dilemma.[2] Regardless of what other countries do, each country, based on purely domestic considerations, wants to reduce their emissions to a. However, all countries would prefer, and benefit from, a situation where all countries choose emission level b (and the global emission level is B), leading to a situation where all countries choose emission level a (and the global emission level is A).

In the right-hand diagram, the situation can also be seen where a single country decides to reduce its emissions to the globally efficient level b. Globally speaking, the value of those emission

2. The Prisoner's Dilemma is commonly used within Game Theory to illustrate why parties because of mistrust will not co-operate, even if in the best interest of both parties to so.

reductions would still be worth the costs borne by the reducing country, but the reductions are made in an inefficiently expensive way, since the cost reduction line followed is steeper than what it would have been if the emission reduction had been shared among the countries.[3] This is because some possibilities of making relatively cheap reductions in other countries are renounced when all reductions are made in one country.

Figure 1 can also be used to illustrate taxes. When each country decides independently on taxes, they would choose a tax that internalizes the costs of climate change borne by the country. That is, the tax should be equal to the marginal valuation of climate-related damages, v. From a global perspective, the efficient tax would be given by the total valuation of emission reductions, W. In setting taxes, there is still the Prisoner's Dilemma aspect of the problem. Each country prefers a situation where other countries have a high tax but where the country's own domestic tax on greenhouse gas emissions is equal to the domestic valuation, v, and where the country ends up in a.

Why move ahead?

So, based on this stylized economic model, the case for moving ahead is very weak, and the case for moving ahead by setting more stringent domestic emission targets is even weaker. Much of the discussion below is about aspects not taken into account in the stylized model.

Looking at data on individual countries' share of global emis-

3. The abatement cost is given by the area under the respective lines, between C and B.

sions of greenhouse gases[4] in 2005, three countries (China 19.1%, the US 18.3% and the Russian Federation 5.2%) each has a share above 5% of world emissions. Another 4 countries (India, Japan, Brazil and Germany) each has a share above 2% of world emissions, and another 14 countries each have a share above 1% of world emissions. The European Union combined has a 13.3% share of world emissions. (CAIT, 2011) Given the emission reductions discussed in order to reach the two-degree target, it is obvious that no country can achieve this on its own. Also, the numbers tell us that very few countries have any significant effect on total global emissions at all.

The conclusion to be drawn from this is that, for almost all countries, the discussion about moving ahead, should probably focus more on what a country can do to affect other countries' actions, rather than on the exact emission reductions that a country should achieve directly (regardless of whether these reductions are achieved domestically or by financing reductions in other countries). Perhaps direct reductions should be considered as a means rather than a goal in itself.

When discussing whether and how a country should move ahead, it seems relevant to ask, what is the purpose of doing so? As will be argued below, the intended effect of doing it will, to a large extent, determine what types of measures to take. It is important to be precise about what the intended effects are and through which channels they are expected to happen. Whether or not a policy is successful should then be judged according to whether it achieves the intended purpose in the end.

One possible reason, not to be discussed further here, is that

4. The numbers include emissions of CO2, CH4, N2O, PFCs, HFCs and SF6, but exclude land-use changes.

there is a preference for a stricter policy. That is, the people in a country want to feel they are not part of the problem. From an economics perspective, this is perfectly possible but not particularly interesting. If there is a preference for the policy itself, it can be determined, through a political process, that it should be provided along with any other desired public goods. For the remainder of this document it will be assumed that the purpose of moving ahead is to actually affect the climate.

As noted above, for individual countries, moving ahead with a mitigation policy will likely have the most significant impact if it induces other countries to reduce their emissions. Three possible ways for a country to use domestic policy to affect the behaviour of other countries are:

- To set an example by showing that it is possible to reduce emissions at a reasonable cost.
- To develop technology or policy models that allow other countries to reduce their emissions at lower cost.
- To gain credibility in international negotiations by unilaterally implementing a more stringent policy.

In terms of the stylized economic description above, the first two points are related to the slopes of the abatement cost curves. The first point is about trying to show that the actual cost curve is perhaps flatter than expected, and that, therefore, larger emission reductions are economically motivated. The second point is about making the actual cost curve flatter. The third point is about trying to counteract the poor incentives given by the Prisoner's Dilemma aspect of the situation. Taking on an active role in internation-

al negotiations could help implement outcomes that are actually preferred by all countries.

In addition to any effects on the climate, policies aimed at climate-change mitigation can also help fulfil other policy goals. Reducing the use of fossil fuels decreases the exposure to fluctuations in international fossil fuel prices. Increasing energy efficiency is, in principle, always good, even though whether it is worth the cost or not may depend on the value assigned to emission reductions. Given that all fossil fuels are available in limited supply, a transition away from using fossil fuels will be forced in the future, regardless of any climate-change considerations. Starting this transition early on can be a good idea for at least two reasons. As the transition will require large, fundamental changes, starting the transition early on can make the transition smoother. Furthermore, since all countries will have to make the transition sooner or later, getting a head start could result in the development of technology and knowledge that can later be exported to other countries. Reducing domestic emissions of greenhouse gases could also reduce emissions of other pollutants that have more direct and local effects. Investing in projects for emission reductions in developing countries could also play a role similar to foreign aid. Besides transferring resources for emission reductions, it could also lead to the transition of technological knowledge.

In the roadmap for moving to a competitive low-carbon economy (European Commission, 2011), the European commission stresses the importance of these kind of side effects of reducing emissions within the European Union. It argues that in the face of increasing fossil fuel prices, reducing reliance on fossil

fuel is important. Furthermore, it argues that many of Europe's key trading partners are moving towards low-carbon economies and if Europe does not do the same, this could harm future competitiveness and employment. In addition to these potential economic benefits, it also argues that the use of fossil fuels would reduce local air pollution.

If the goal of the policy is climate-change mitigation, the policy will probably be more efficient if it is formulated to reach that particular goal. However, to the extent that there are synergies, the consideration of multiple goals may be desirable. Combining multiple policy goals could also make the policies more feasible politically.

Background on Sweden

Sweden has established a climate-change mitigation policy; for example, by having a tax on CO2 emissions since the beginning of the 1990s, and the current tax rate (SEK 1.05 per kg) is above the price on emissions that is estimated to bring down emissions by one half by 2050 (Carlén, 2007). In 2009, the Swedish emissions of greenhouse gases were 17.2% lower than emissions in 1990 (Naturvårdsverket, 2011). So, it can be argued plausibly that Sweden has already moved ahead and at the same time had strong economic growth.

Given that the emissions have already decreased a lot, it is often argued that further domestic emissions reductions are costly compared to other alternatives. Eklund (2009) calculates that further reducing Swedish emissions by 20% would cost approximately SEK 30 billion per year if done domestically. This

corresponds to roughly 1% of GDP. If an equivalent reduction of emissions were done using mechanisms where emissions are reduced in other countries, the cost would be approximately SEK 1 billion per year. Carlén (2007) also argues that achieving emission reductions by buying emission rights, rather than making domestic emission reductions, would significantly lower the cost of the reductions. Carlén even finds that completely offsetting all Swedish emissions by buying emission permits — and thereby making reductions in other countries and, in a sense, making Sweden 'climate neutral' — would be cheaper than the current targets for 2012.

In a report by McKinsey (2008), the costs of different ways of reducing greenhouse gas emissions in Sweden, are quantified. The report estimates that SEK 500 per ton of CO_2 equivalents is a reasonable estimate for the future price of emissions within an emissions trading scheme. Therefore, it uses this as a reference point and looks at measures for emission reductions that cost less than this. The author finds that the percentage emission reduction potential is larger than, or at least as large as, the potential in other countries (based on comparisons with Germany, the US and Australia). This would give reductions of 10% in 2020, compared to 2005, and 23% in 2030, compared to 2005.

The report also finds that increased capacity for renewable energy generation and increased energy efficiency would not decrease emissions in Sweden that much, but clean electricity could be exported and thereby help reduce emissions globally. For larger emissions reductions, the study finds that the reduction costs increase quickly and that reductions would require much more drastic changes.

In the McKinsey study, a significant share of the reductions would, in fact, give negative costs. That is, some of the measures to reduce emissions would, besides the emission reductions, give direct economic gains. A similar conclusion, reached by a governmental investigation on energy savings (Energieffektiviseringsutredningen 2008), also found that the potential for improvements in energy efficiency that would lead to economic gains corresponds to more than 10% of energy use in Sweden (about 11% of final energy use and about 14% of primary energy. See Energieffektiviseringsutredningen, 2008:p.23, Table 4).

It is worth pointing out that, while Sweden has among the lowest per capita emissions of all industrialized countries, the emissions are still way above what is considered sustainable in the long run. In 2009, Swedish per capita emissions were approximately 6.5 tons of CO2 equivalents (Naturvårdsverket, 2011; assuming that the Swedish population is about 9.3 million). In relation to the two-degree target, it is often said that per capita emissions in the world will need to be around 2 tons in 2050 and 1 ton in 2100.

Finally, it can be noted that, in 2005, Swedish emissions amounted to 0.18% (CAIT, 2011) of world emissions. So, Sweden is definitely one of the countries where mitigation policies will probably be much more efficient if they can affect the behaviour of others.

Structure of the document

The following three sections discuss a broad range of literature based on three issues that are related to moving ahead: the first is

carbon leakage; the second is technology; and the third is the role that a single country can play in international negotiations. The document concludes with a summary and discussion of the different ways that a country could affect climate change by moving ahead.

Chapter 3

Carbon leakage

Carbon leakage refers to an increase in emissions in other countries as a direct effect of emission reductions in one country. Carbon leakage can happen in different ways. The International Energy Agency (IEA) (2008a) identifies three channels for carbon leakage: the short-term competitiveness channel (changing market shares); the investment channel (it is more attractive to invest in production capacity in countries with less strict regulation); and the fossil fuel price channel (decreased demand for fossil fuels from one country decreases the price and increases fossil fuel use in other countries).

It is not difficult to see why the risk of carbon leakage is greatly discussed in the context of moving ahead. However, in the light of the above discussion, about the purpose of moving ahead, the importance of leakage must be judged in relation to the intended goal, and whether or not it makes it more difficult to achieve that goal. If the emission reductions in a country are done to decrease total global emissions directly, the resulting direct effect is very important. Hence an evaluation of the risk for carbon leakage is crucial. However, as discussed above, it is not likely to be worthwhile for a single country to reduce its emissions for the purpose

of reducing global emissions by its share only. If, on the other hand, the purpose of moving ahead is something else, carbon leakage may be less important.

In this context, it is worth mentioning the somewhat different perspective on policies aimed at reducing fossil fuel use provided by Sinn (2008). The argument put forward there is that the supply of fossil fuels consists of a number of owners of finite fossil fuel resources. These resource owners will keep extracting the fuels as long as the price is higher than the extraction cost. If the extraction costs are relatively low, this means that very strong and globally coordinated action is required to significantly affect total fossil fuel use aggregated over time. This would imply that, at least over time, there should be a great deal of carbon leakage, since the action of a few countries cannot affect total fossil fuel use. However, given that the assumption of low extraction costs does not seem to be fulfilled for the entire supply of fossil fuels, more research is needed, and is being done, to determine the practical importance of this argument.

Pollution havens

The discussion of carbon leakage is closely related to the discussion of 'pollution havens'. A pollution haven is a country that has lax regulation of polluting activities. The idea is that pollution-intensive production would tend to move to such countries in order to avoid costs associated with complying to strict environmental regulation.

Pollution haven hypothesis and pollution haven effect

Copeland and Taylor (2004) provide a thorough discussion of pollution havens. They distinguish between a pollution haven hypothesis and a pollution haven effect. The first being that more dirty production is located to countries with more lax regulations, and the second being that, on the margin, the strength of regulations will affect plant location and production decisions.

In econometric (or statistical) terms, the difference between the hypothesis and the effect is similar to the difference between correlation and causality. The pollution haven hypothesis states that polluting production should be correlated negatively with strictness of environmental regulation, while the pollution haven effect says that stricter environmental regulation causes polluting activities to be located elsewhere.

To make the distinction between the concepts clearer, consider first what the pollution haven hypothesis predicts. It predicts that polluting production should be located to countries, or regions, with less strict environmental regulation. Another implication is that following trade liberalization, production would tend to move from countries with stricter regulation to countries with less strict regulation. The implications of a pollution haven effect are much less clear. The pollution haven effect only suggests that polluting production should be located to countries with more lax environmental regulation, if all countries are identical in all other aspects. If countries differ in other respects except the strictness of environmental regulation, the effects of these differences could be larger and reverse the direction of the pollution haven effect. One example of such differences could be that countries with stricter

regulation also have a comparative advantage in polluting production. The comparative advantage could be better access to inputs required for polluting production, such as capital and skilled labour. If this comparative advantage is strong enough, production could instead move to countries with stricter regulation.

For the present discussion, the distinction between the concepts is very important, and the pollution haven effect is more relevant. This is because carbon leakage is concerned with the effects of changing the strength of regulation. So, the interesting question is what effects the policy itself might have.

Why the pollution haven hypothesis may not hold

In their theoretical analysis, Copeland and Taylor (2004) find that there is little support for the pollution haven hypothesis. This is mainly because that environmental regulation is just one factor guiding investment and production decisions. Costs of compliance to environmental regulation are usually just a small part of total production costs. So, to the extent that other important factors for production and investment decisions are correlated with the strength of the environmental regulations, these other factors can often be more important than the effect of the regulations.

An example of why such correlations could exist can be found in the literature on the environmental Kuznets Curve (see e.g. Copeland and Taylor 2004). There it is often argued that the demand for stricter environmental policy comes with higher income and higher level of development. This implies that countries with stricter environmental regulations are often more developed and have more capital-intensive production. Since these are factors

that favour emission-intensive production, this would lead to more emission-intensive production in countries with stricter environmental regulations. So this means that it should not be expected that the pollution haven hypothesis holds.

Antweiler et al (2001) find support for other factors being more important than environmental regulation. They reveal that rich countries have a comparative advantage in producing dirty, capital-intensive goods, and that trade tends to lead to an increase of such production in the rich countries. The results of Dietzenbacher and Mukhopadhay (2007) can also be interpreted as support for this view. They find that increased trade decreases pollution in India; that is, they reject the fact that India should be a pollution haven. This could be explained by the Factor Endowment Hypothesis, assuming that India has a comparative advantage in labour-intensive production (although their data does not allow them to test this more specifically).

Testing empirically for a pollution haven effect

As mentioned above, the interesting question in this context is whether or not there is a pollution haven effect. Testing empirically for a pollution haven effect is, however, much more difficult than testing the pollution haven hypothesis. Given the mixed evidence regarding pollution havens, and that much discussion about moving ahead focuses on carbon leakage, it seems relevant to consider the technical issues involved in testing for a pollution haven effect in more detail.

Since a pollution haven hypothesis suggests that production causing environmental damage is located in countries with less strict regulation, relatively simple cross-country regressions will

be sufficient. When testing for a pollution haven effect, on the other hand, the effect of the regulation itself must be isolated. That is, the causal effect of the policy should be measured.

Many papers, especially early on in the literature, do not make a clear distinction between the pollution haven hypothesis and a pollution haven effect. They do cross-country regressions including control variables to control for some of the observable differences. Typically, the results in these papers show that there is no effect of regulation, or that it goes in the other direction. For example, see Jaffe et al (1995) for a survey of this early literature. However, as said above, this implies that the pollution haven hypothesis does not hold, rather than that there is no pollution haven effect.

Econometrically, testing for the pollution haven effect requires dealing with problems of unobserved heterogeneity and reversed causality.

As said before, other differences between countries could be a stronger determinant of trade flows and location of production, than the strictness of environmental regulation. When testing empirically for a pollution haven effect, this presents a problem of unobserved heterogeneity. Some of the differences may, of course, be observable and, to some extent, it may be possible to control for these differences, but completely controlling for heterogeneity is difficult.

The strictness of environmental policy may also be endogenous. One example is the possible explanation for the environmental Kuznets Curve described above. That is, that there are stronger preferences for environmental regulation in more developed countries. Another possible source of endogeneity of policy

is that countries with big pollution problems may be more inclined to adopt stricter regulations. This would lead to stricter regulation being correlated positively with more polluting production. The details of the regulation may also matter. Countries where strict regulation could lead to serious losses in competitiveness, may try to compensate for some polluting industries. If this is the case, measures of regulation strictness, that does not take this into account, will overestimate the strictness of regulation in countries with extensive polluting production. When looking empirically for a pollution haven effect, these issues indicate a problem of reversed causality, where the outcome variable affects policy (or the measure of policy), instead of the other way around.

Ederington et al (2003) test and find support for two other reasons of why it is difficult to find a pollution haven effect empirically. The first of these is that much trade takes place between developed countries that have similar or converging environmental standards. So the effects of regulation on trade between these countries may be small. They find that the effects are larger when looking at trade with countries with lower income and less strict regulations, compared to when looking at trade with more similar countries. The second reason is that more polluting industries tend to be less mobile (or 'footloose'). When averaged over different industries, this tends to result in underestimation. They find support for this as well. They also test for the idea that the low-cost share of compliance costs in total production costs would tend to the effects being small. They do not find support for this.

A study that tries to identify the causal effect of strength of policy is that of Greenstone (2002), which looks at the effects of the United States (US) Clean Air Act. The specification includes

plant-fixed effects; industry by period-fixed effects; and county by period-fixed effects in plant-level models for the growth of employment, investment and shipments. The study uses the principal instruments of the Clean Air Act Amendments, the pollutant-specific, county-level attainment/non-attainment designations, as its measures of regulation (non-attainment means that the county does not fulfil the specified standards and, therefore, there are more strict regulations in these counties). The study finds significant effects of the strength of regulation on jobs, capital stocks and production.

Levinson and Taylor (2008) construct a theoretical model and use it to analyse how different empirical problems lead to the underestimation of the pollution haven effect. In their empirical analysis they find both statistically and economically significant negative effects of environmental regulation on competitiveness.

Brunnermeier and Levinson (2004, in particular Tables 3–5) give a thorough survey of the different studies looking at the effects of environmental regulations on different economic outcome variables. The studies vary a lot in terms of empirical methodology, choice of outcome variables and measure of stringency of regulation. Brunnermeier and Levinson discuss how these differences affect the results. The conclusion drawn is that the most important determinant of whether or not an effect on trade or competitiveness can be found, is whether a sound empirical strategy is used or not. If unobserved heterogeneity and/or reversed causality are properly corrected for, a negative effect on competitiveness is typically found. It is worth mentioning, however, that there are studies using more carefully constructed empirical strategies that do not find significant effects.

From the evidence cited above, I draw the conclusion that it is likely that there is a pollution haven effect, but that the effect may be smaller than expected. The size of the effect for specific countries may also vary greatly depending on, among other factors, industrial structure.

The European Emissions Trading Scheme (ETS) and carbon leakage

The European Emissions Trading Scheme (ETS) has been in place since 2005. The International Energy Agency (IEA) and OECD have conducted two different studies to see whether ETS has resulted in any carbon leakage. One of the reports (IEA, 2008a) looked at the effects of ETS on cement, iron & steel and primary aluminium. They cite a number of studies trying to predict the degree of carbon leakage. For all these sectors the predicted leakage is significant. In the other report (IEA, 2008b), they look more closely at Aluminium. When looking at the data, they do not find any significant indications of carbon leakage occurring between the years 2005 and 2007. They do not, however, draw the conclusion that carbon leakage will not occur in the future. Important reasons why carbon leakage may not show up in the examined data is the short time span and the relatively weak impact of the scheme so far (the emission permits were distributed for free in relatively large quantities, and many of the companies had long-term energy contracts that limited the impact of increasing costs of energy).

As noted by Stern (2006, ch 11), when looking at effects of changed trade and production patterns, the costs of stricter regulations can easily be overestimated. Significant changes will only

happen in a limited set of industries that comprise a limited share of the production in a country. Also, if there are some particularly problematic sectors, special measures could be taken to soften the blow to these sectors.

This is also the conclusion of some studies looking at the effects of EU Emissions Trading Scheme EU-ETS on competitiveness in the UK and Germany. Hourcade et al (2007) find that for the UK, only a few sectors are likely to be affected. These sectors jointly contribute about 1% of GDP. The competitiveness problems for these sectors could be reduced by the free allocation of permits. There is, however, a risk that the firms would move the emitting production elsewhere and then sell the permits. If this happens, the free allocation would reduce the competitiveness issues for the sectors, but it may not address the carbon leakage problems. Similarly, Graichen et al (2008) find that only a few sectors in Germany face significant competitiveness concerns.

The OECD (2009) estimate that if the EU were to reduce its emissions unilaterally by 50% for 2050, the carbon leakage would be 13% in 2020, and 16% in 2050. The figures for all greenhouse gases are smaller; 6.3% in 2020 and 11.5% in 2050. If all developed countries (or, more precisely, the so-called 'Annex I' countries) undertake similar measures, the leakage of greenhouse gas would be only 0.7%, Also, if Brazil, China and India were to take comparable actions, the leakage would be as small as 0.2%. Expressed differently, if the EU reduces emissions unilaterally by 50% until 2050, 84% of these reductions would translate into a reduction of global emissions. If, at least, all Annex I countries made emission reductions, almost all of these reductions would result in actual global emission reductions.

The Swedish case

For Sweden, Nilsson (1999) tried to predict the effects of increasing the carbon tax rate unilaterally in Sweden, as well as the effect of all EU countries setting the same higher tax rate. This was done using a general equilibrium model for two different scenarios, where there are exemptions for certain industries in one of the scenarios. The conclusion is that, in the unilateral case, there is significant carbon leakage. The Swedish emissions are reduced significantly while the changes in total EU emissions are small and, in one of the scenarios, total emissions actually increase slightly. The reason for this is that there is carbon leakage to other EU countries where production is more emission-intensive. The study does not take into account the value of decreasing emissions, and without this consideration, the welfare loss is larger if a higher carbon tax is implemented in all of the EU, compared to a unilateral Swedish tax increase. In the latter case, however, total EU emissions are reduced significantly, but the study does not give the total world emissions, which arguably is the interesting measure.

Given that Sweden has, for some years, had more stringent carbon tax policies than most other countries, it seems that this should be an interesting subject of empirical study. I have not been able to find any empirical studies on carbon leakage directly. There are, however, studies that measure Swedish emissions from the consumption side instead of the production side. That is, they calculate the emissions caused by production of the goods consumed in Sweden, rather than emissions caused by production of the goods produced in Sweden.

Carlsson-Kanyama et al (2007) calculate the emissions caused

by goods consumed in Sweden during a time period when the reported Swedish emissions (from the production side) were 54 MtCO2 per year. Depending on the method used, the total emissions from Swedish consumption is estimated at 57, 61, 68, 109 MtCO2. The lowest estimate is based on emissions from all goods being calculated as causing the same emissions as if they were produced in Sweden. The highest estimate is based on the reported emission intensities from the exporting countries. This is just a snapshot in time which makes it difficult to draw any conclusions about carbon leakage.

Peters et al (2011) look at how emissions, caused by production of traded goods, have changed over time. This allows them to calculate the emissions caused by goods consumed in a country. The data indicates that even though emissions from traded goods have increased worldwide, Sweden's emissions from consumption, including imports, decreased by 13% between 1990 and 2008. This decrease is similar to the domestic emission reductions.

So, while these numbers do not allow for any direct calculation of the amount of carbon leakage, it does not seem that the domestic emission reductions made in Sweden have been compensated for by increasing the imports of emission-intensive goods. The calculations made by Carlsson-Kanyama et al (2007) do, however, indicate that imported goods tend to be more emission-intensive than goods produced domestically. This means that production that moves to other countries increases total emissions.

Conclusions about carbon leakage

Based on the evidence cited above, there seems to be a real risk of carbon leakage when moving ahead with mitigation policies, but the consequences seem to be quantitatively smaller than expected. Again, how problematic carbon leakage is depends on the reason for moving ahead. It implies that the direct effects, in terms of emissions, from a stricter policy are smaller than expected if these effects are not taken into account. However, if the reason for moving ahead is something other than direct emission reductions, the implications are less clear.

Based on the studies of the EU-ETS, it seems that the aggregate effects on countries, of the competitiveness issues, may not be that large given that only a small share of the economy is affected. However, this does not mean that the carbon leakage problem is small. Domestic emission reductions may still be counteracted by emission increases elsewhere. If production moves to countries with higher emission intensities, these effects may be significant.

Given the forward-looking nature of many of the decisions driving carbon leakage, Stern (2006, chapter 11) notes that the amount of carbon leakage depends on the expectation of eventual global action. To the extent that other countries are expected to follow, the competitiveness and leakage concerns of moving ahead should be decreased.

4

Chapter 4

Technology

Technological change will likely be very important for climate-change mitigation. A significant reduction in emissions, without a significant reduction in production, requires a significant technological shift, both in terms of energy efficiency and in terms of the use of alternative energy sources.

That technology is endogenous to climate-change policy has been increasingly recognized. If mitigation policy increases the price of emissions, this is likely to induce invention, and increased use, of technology for reducing emissions. It has also been found that the costs of reducing emissions are reduced significantly if this endogenous response of technology is taken into account (see Edenhofer et al, 2005; Popp, 2004).

Alfsen and Eskeland (2007) discuss the importance of technology as part of climate mitigation policy, and the risk that the Kyoto Protocol does not stimulate research on technology for long-term emission reductions. Research is a forward-looking activity and the short time span of the Kyoto Protocol is not nearly enough to provide the right incentives. They also argue that there are important complementarities between policies aimed at research and policies aimed at emission reductions.

Successful research brings down the costs of emission reductions, at least in the future, so if there is credible commitment to carry out research on abatement technology, this makes it more likely that countries would agree on significant emission reductions in the future. A carbon cap-and-trade system provides incentives to use available technology efficiently. Alfsen and Eskeland, therefore, propose that international agreements on research subsidies and emission reductions should be negotiated jointly. Furthermore, they argue that global action is less important when it comes to investments in technology than when it comes to committing to emission reductions. They propose the formation of a long-term (they use a time frame of 20 years as an example) technology-oriented treaty among a 'coalition of the willing', in which countries agree to contribute to joint research on abatement technology, and where the research is carried out by international research teams to ensure that knowledge is used and transferred efficiently.

So, there is plenty to say about the role of technology in climate change mitigation. When discussing technology in relation to moving ahead, at least three different aspects seem relevant. Firstly, early investment in technology required for climate-change mitigation could lead to technological advancements that generate profits in the future. Thus investing resources in research on technology for mitigation could be profitable. Secondly, even if investments in technology for mitigation are not profitable, they could still have an effect on global emissions to the extent that it makes emission reductions in other countries less costly, and therefore reduces total emissions at a lower cost compared to the country reducing the domestic emissions. Thirdly, a country

that wants to move ahead, in order to provide an example that it is possible to reduce emissions at a reasonable cost, must make sure that use of existing technology and the invention of new technology is done in a way that minimizes the costs of reducing emissions.

Below, the use of policies in stimulating research on, and the use of, technologies for dealing with environmental problems will first be discussed in more general terms. After that, some aspects, relevant to the context of moving ahead, will be discussed.

Policies for stimulating technological change

The fundamental problem of climate change is that greenhouse gas emissions cause externalities that impose costs not captured by market prices. The development of abatement technology is a means to lower the cost of reducing emissions. The following section will discuss the effects that policies, aimed directly at mitigating climate change, can be expected to have on abatement technology. The section after that will discuss the role for policies aimed, instead, at the process of technological change. Aldy et al (2010) provide a good, non-technical, introduction to, among other things, how different policy tools can be combined to achieve efficient climate-change mitigation, including stimulating mitigation technology. Fischer and Newell (2008) give a more model-based overview of these issues.

Environmental policy and technological change

There has been plenty of research on environmental policy and technological change. See Jaffe et al (2002) for a good introduction to, and overview of, this research.

According to Schumpeter, the process of technological change is often divided into three steps. The first step, invention, is the development of a new product or process. The second step, innovation, is when a new product is made available in the marketplace. The third step, diffusion, is when firms or individuals start using the innovation.

Instruments for environmental regulation are often divided into two broad categories: market-based; and command-and-control (see Sterner, 2003, for a discussion of other ways of characterizing different possible policy instruments). The market-based policies include taxes and tradable permits. Command-and-control instruments impose restrictions on production. This can be a maximum amount of allowed emissions per produced unit, or using a particular technology.

Market-based instruments are generally favoured by economists. One of its advantages is that a given reduction is achieved in a more efficient way. The cost of reductions often varies a lot between different activities and firms. With market-based instruments the decisions on the exact amount by which to reduce emissions in individual activities are left to those carrying out these activities. These actors can be expected to have better information about different alternatives. So, market-based instruments will tend to equalize marginal abatement costs between all possible ways of achieving reductions. Another argument in favour of market-based instruments is that they provide a continuing incen-

tive to reduce emissions further, while command-and-control instruments only give incentives to reduce emissions until the requirements are fulfilled.

Environmental policy will also affect the rate and direction of technological change. When discussing mitigation of climate change, the environmental policy is aimed at decreasing the emission of greenhouse gases. This means that for firms with production that causes emissions, the regulation increases the cost associated with, or constrains the use of, certain inputs and production processes. This gives an incentive to start using technology that causes fewer emissions. So, environmental policy will affect the diffusion of technology. It will also be more attractive to develop and market new technology that causes fewer emissions. Thus, environmental regulation will also affect invention and innovation of new, less emitting technologies.

A number of studies have tried to estimate the effects of regulation on technologies for abatement. See Vollebergh[1] (2007, in particular Tables 1–3) and Jaffe et al (2003) for a survey and discussion of this literature.

There is plenty of evidence that environmental regulation leads to increased research on technologies that reduce the cost of complying with the regulation. Lanjouw and Mody (1996) look at patenting data for different countries between the years 1971 and 1988, and find that the share of patents related to abatement technology is correlated positively to pollution abatement costs. They also find an effect on imports of foreign technology, either by using patented technology developed in other countries, or by importing technology embodied in abatement equipment. Jaffe and Palmer

1. Available at http://papers.ssrn.com/sol3/papers.cfm?abstract_id=991612

(1997) find that (lagged) costs of complying with environmental regulation have a positive and significant effect on Research and Development (R&D) expenditure, but they do not find an effect on successful patenting.

Even though it is not an effect of environmental regulations, looking at variation in energy prices is also of interest here, since it captures the effect of changes in relative prices, such that polluting activities (energy use) become more expensive. Popp (2002) finds a positive and significant effect of energy prices on patenting of technology that increases energy efficiency.

R&D is a forward-looking activity. Therefore, the expectation of future policies matter a lot. The IEA (2007) discusses the importance of credible and predictable climate-change policies. It estimates how policy uncertainty affects investment decisions in the power-generating sector. It finds that it can be a significant part of the risk associated with investment in power plants, and that it can affect investment timing and choice. The IEA does, however, argue that, especially if climate policy is set over sufficiently long times, fuel price uncertainties can be larger than the policy-related uncertainties.

It is also noted that when an old regime (such as Kyoto) comes close to an end, the uncertainty will be worse since the policy can be expected to change in a few years' time. So, unless the new policy is decided well in advance of the old agreement's expiration (as is not happening at the moment), there could be some years where investment decisions are postponed owing to policy uncertainty.

Policy aimed directly at technological change

As a result, environmental regulations are likely to affect the development and diffusion of abatement technology. In the absence of further market failures, correcting for climate externality should, in principle, be enough. Technology would be demanded and developed, based on its cost-effectiveness in reducing greenhouse gas emissions. There are, however, also other market failures involved in the process of developing and adopting new technologies.

Positive externalities of technological change

The process of technological change comprises externalities, but, unlike the externalities caused by emissions, the externalities here are typically positive. Jaffe et al (2005) divide these externalities into knowledge externalities and adoption externalities.

The process of innovation (Jaffe et al, 2005, collapsed the steps of invention and innovation into a single step called 'innovation') generates new knowledge. Some, but not all, of the social value of this new knowledge will be captured by the innovator. This means that the value to those actually doing the innovation will be smaller than the social value of the innovation.

The positive externalities associated with innovation and adoption implies that an unregulated market will provide too little technological change. When combining this with the negative externalities from emissions, Jaffe et al (2005) note that the different externalities amplify each other. Negative externalities from emissions imply that emission-reducing technology is given

a too low value, and that too few resources are used for it. Underinvestment in such technology is amplified by the absence of the positive externalities from innovation and the adoption of such technology.

Popp (2002) finds that, apart from energy prices, the existing stock of knowledge has a positive and significant effect on innovation, which speaks in favour of the view that research is associated with positive knowledge externalities.

Based on theoretical modelling, Acemoglu et al (2011) argue that these positive externalities imply that a policy aimed directly at the research process is needed, and that postponing the use of this kind of policy may be very costly. The reason for this is that 'dirty' (which can, in this context, be interpreted as fossil fuel based) technology is currently much more mature than 'clean' technology. Private firms investing in research on new technology can benefit much more from past research, if they invest in dirty technology compared to if they invest in clean technology. This means that privately funded research will, to a large extent, tend to be directed towards dirty technology. The positive externalities also imply that it will take time and resources to develop clean technology to the point where it can replace dirty technology. If investments in research on clean technology are not made in time, reducing the use of dirty technology can be very costly.

In the process of adopting a new technology, there is often a kind of dynamic increase in returns. Jaffe et al (2005) identify three sources of such dynamic increased returns. As a technology spreads, those who have not yet adopted it can benefit from observing the experience of those that have. This means that adopting a new technology gives a positive externality called

'learning-by-using'. On the other side of the market, as a producer gains experience of a technology, the production costs typically decrease. There is another positive externality called 'learning-by-doing', to the extent that these improvements also spill over to other, current or potential, producers using the technology. If the value of using a product increases the number of others also using the product, there are network externalities.

McDonald and Schrattenholzer (2000) give an overview of different attempts to estimate how much learning decreases the cost of using different types of energy technology. The amount of learning is measured in terms of a learning rate. This is the percentage decrease in costs of using a technology as the experience of using it doubles. They find that the typical value for regressing costs on experience, and assuming constant learning rates, are 15–20%, with some variation. They also find some evidence that the learning rate decreases as the technology matures.

Different policy measures can be appropriate for research at different levels. Newell (2009) divides research into three different levels: basic research; applied research; and development of commercial products. It is more difficult to appropriate the social benefits of research at more basic levels. Therefore, it seems reasonable to direct public funding towards pre-commercial research. There is also the stage of deployment, where products actually become used. To stimulate deployment, a policy that puts a price on emissions can help to create markets for these products. Starting to use a completely new product or technology can be particularly risky (in terms of technical, market and regulatory risk) and can also generate lots of new knowledge, the benefits of

which are difficult to appropriate. This means that it can be a good idea for governments to fund the first demonstration projects.

Other reasons for policy aimed at technology

When it comes to the technology required for climate-change mitigation, some of the technologies require large infrastructure investments. This makes it unlikely that the market alone will provide technologies efficiently, and so there could be scope for active policy intervention to improve efficiency.

Apart from externalities, there can also be other market failures. One example of such a problem is asymmetric information. This can be a problem if investment decisions are made by people other than those who will benefit from, for example, the decreased energy used. This can be described as a principal agent problem. A typical example of that can be investments in insulation or other energy efficiency measures in houses (see Söderholm and Hammar, 2005). These types of investments are often made by the construction companies or landlords, while the energy bill is paid by the people living in the house. Those making the investments often have better information about the resulting energy savings, making it difficult to fully appropriate the value of those investments in terms of the rental or sale value of houses. This can result in too low investments in these types of energy saving measures.

Enkvist et al (2007) indicate that, globally, there are a number of measures that could be taken that would reduce the CO2 emissions at negative cost; that is, reduce emissions and at the same time give direct economic benefits. As said above, studies for the case of Sweden reach the same conclusion (McKinsey, 2008; Energieffektivitetsutredningen, 2008).

Consequently, an implication from this is that it should be possible to reduce emissions at negative cost. The question is, why that has not been done already? If the costs are calculated correctly, and they would, in fact, be negative, it seems that something prevents them from being implemented. In Energieffektiviseringsutredningen (2008), some different reasons are suggested. One is the principle agent problem discussed above. Another reason is the lack of information. To the extent that these kinds of problems prevent implementation of measures that would decrease emissions at negative costs, it does not seem very likely that stricter environmental regulation would overcome the problem and induce implementation. Instead, other types of policy tools should be used to induce these emission reductions.

Difficulties in conducting policies aimed at technology

It appears likely that the use of policies aimed directly at innovation and diffusion of emission-reducing technology can improve efficiency. This type of policy is, however, controversial and difficult to implement in practice. The problem is the trade-off between affecting the direction of technological change, on the one hand, and leaving as much of the decision-making as possible to those best informed about the issues, on the other. Many economists argue that it should not be the task of policy-makers to 'pick winners' (see Jaffe et al, 2005). Samakovlis (2011) describes some Swedish examples of policies aimed at believed 'winners' that, in retrospect, turned out not to be winners. Newell (2009) refers to some very notable failures in government funding of demonstration projects.

Aldy et al (2010) argue that, in principle, one policy instrument should be used for each market failure. Policies aimed at the externalities of climate change are relatively simple. Just price all emissions of greenhouse gases uniformly, at the costs caused by the externalities. The technology related market failures, on the other hand, are more diverse and appropriate policy measures must, to a large extent, be assessed on a case-by-case basis. Aldy et al find that the available literature provides limited guidance on the design of policy instruments aimed at the R&D process.

When large infrastructure investments are required, as is often the case with technology for climate-change mitigation, there can be a significant lock-in-effect. If there are competing technologies and one is chosen, it can be very costly to reverse the decision in the future. It is then particularly important to choose the right one.

When considering a policy aimed directly at the development of a new technology, the interaction between government and market-funded research must be considered. Newell (2009) argues that the R&D spending by the private sector is so large that unless the incentives of private R&D spending are changed to favour investment in technology for decreasing greenhouse gases (e.g. through taxes), any public R&D spending will 'likely push against an insurmountable tide'. However, to the extent that research uses scarce resources (e.g. researchers), there can be costs in terms of crowding out other research.

So, a policy aimed directly at technological development should, in principle, improve efficiency. There may, however, be a cost in terms of crowding out other kinds of research. There is also a tension between trying to steer the technological development in a desired direction and making sure that those who are

best informed make the decisions about what type of research to pursue, and which technologies to adopt.

Technology and moving ahead

The previous section concerned the role of technology in dealing with environmental problems. When technology is considered in the context of moving ahead, some further issues are relevant.

This section will start with a discussion of the literature on the Porter Hypothesis. After that, the issue of inducing technological change by pricing emissions versus aiming policy directly at the technology invention and adoption process will be revisited. The arguments put forward here will tip the scales somewhat in favour of policies aimed directly at the process of technological change.

The Porter Hypothesis

Some authors have expressed a very optimistic view about the possibility of increasing efficiency to reduce the costs of implementing stricter environmental regulation. A well-known example of this is the Porter Hypothesis (Porter & van der Linde, 1995). There are some different versions of this, but essentially it says that carefully formulated environmental regulations can trigger efficiency improvements that actually make the costs of stricter environmental policy negative, even when excluding any positive effects from improved environmental quality.

Different theoretical explanations for why there could be these types of efficiency increases have been proposed. Greaker (2006) argues that more stringent regulations can stimulate an upstream sector that supplies abatement technology. This stimulation

would lead to increased competition in that sector and the price of abatement technology could fall, leading to increased final good production (although not necessarily lower abatement costs). These effects will be strengthened to the extent that there are spillovers between the R&D efforts of different abatement technology producers.

Since the Porter Hypothesis was formulated, it has been debated among economists (Jaffe et al, 2003), and there seems to be some kind of emerging consensus that this can happen in some cases (the evidence cited in favour of the hypothesis is often in the form of case studies), but it cannot be expected to be generally true for entire economies.

Popp (2005) proposes that taking the uncertainty of R&D outcomes into account could explain the differing results of the Porter Hypothesis. Investments in technology will be undertaken if the expected value of doing them is positive. If a firm faces stricter regulation, some investments, that were not deemed profitable without regulation, will seem profitable. Given the uncertain outcomes, some of the investments are likely to turn out to have been ex-post profitable, even in the absence of stricter regulation. This is consistent with the case studies showing that compliance with stricter environmental regulations may have negative costs, and the opinion that this is not generally the case.

For the Swedish case in particular, Brännlund (2007) argues strongly that the Porter Hypothesis does not hold.

Technology and pricing emissions unilaterally

It seems that, generally, putting a price on polluting activities should perhaps be the preferred way of inducing development of

abatement technology. In the context of moving ahead, however, the case is less clear.

There are a number of theoretical papers investigating the effects of unilateral efforts of reducing emissions, when taking the effects on technology into account (Di Maria and Smulders, 2004; Di Maria & van der Werf, 2008; Golombek & Hoel, 2004). In these papers, unilateral emission reduction efforts affect technological development in countries with stricter regulation. These technological advances then lead to technology spillovers in the other countries. Without technological spillovers the models predict increasing emissions in other countries, but the technological spillovers lessen this effect and in some cases even reverse it, making the other countries reduce their emissions. All these papers, however, use two-country models, which makes them more relevant for cases where a significant share of the world's countries coordinate on emission reductions. So, they seem more relevant for an agreement such as the Kyoto Protocol rather than for single countries moving ahead.

When a single country moves ahead, the size of the market for the technology is much smaller than if a large number of countries puts a price on emissions. Thus, it is not definite that pricing emissions will be effective in inducing invention. For the adoption of existing technology, the difference is probably smaller.

In the context of moving ahead, the effect of environmental policy instruments on technological change must also, reasonably, be weakened, to the extent that there is carbon leakage. If one country has a stricter policy, this only induces technological change so that production stays in that country. If production moves, the incentives for technological change go away.

If aiming for developing technology that makes other countries' emissions reductions cheaper, it is not clear that pricing domestic emissions induces the invention of the required technology. Although putting a high price on emissions in one country induces technological change, it is likely to induce change in a direction that makes emission reductions cheaper in that particular country. This will then only help to reduce costs of emission reductions in other countries if the same technologies are useful in those countries.

Policies aimed directly at the process of technological change

If a country aims to develop new technology that either decreases other countries' costs of making emission reductions or that provides business opportunities, reducing emissions unilaterally may not be the way to go. In order to fulfil these goals, policy instruments should perhaps instead be aimed at stimulating research on technologies that fit well with the knowledge and industry structure within their own country. Thus, there should be a focus on research where resources spent are likely to either be profitable to sell to other countries, or will allow other countries to reduce emissions at a lower cost. Alfsen and Eskeland (2007) say that it is probably more important if Sweden can make a 'giant leap' on a specific, perhaps narrow, area of technology, rather than making broader but more modest progress.

When trying to channel resources into research within fields that fit well with the knowledge and industry structure of a country, rather than on technologies that will help reduce emissions domestically, there are some policy measures that can be

used. Their applicability may also be better for countries moving ahead. Besides investing directly in research or subsidizing research carried out by domestic firms, a country could attempt to attract research by foreign firms. It seems likely that there will be private investment in research on abatement technology by large international firms. By providing a good environment for research, such research investments could be attracted to the country. This can be done in different ways. For instance, through investments in research, it should be possible to create centres of expertise for certain types of technology that would make it attractive for international firms to locate their research close to these centres. Other ways of making a country attractive for research investments could be to provide the required infrastructure, testing grounds for technology, and properly educated labour. A country that moves ahead in this way could establish itself as a leader in this type of technology. Being a technological leader could be profitable in its own right and could also improve the perception of the country taking climate change seriously.

Crowding out and scale effects

It does not matter for the climate where a technology is developed once it becomes used. This is similar to the irrelevance of the geographical location of emission sources. The question then arises whether there is a problem similar to carbon leakage for technological development; that is, can the effects of investments in research in one country be dampened by decreased research in other countries? Whether or not this will happen is closely related to whether there are decreasing or increasing returns to research over time. If there are decreasing returns, successful research will

make future research more costly and this could lead to crowding out. If, on the other hand, there are increasing returns, successful research decreases the costs of future research, and research spending in one country could encourage more spending in other countries. There seems to be more support for increasing returns (Jaffe et al, 2003), implying that crowding out should not be a big problem.

If considering moving ahead through technological development, for the purpose of developing technology that will generate future profits , a relevant issue is whether or not there is a first-mover advantage. Spillovers, such as learning-by-doing, imply that those who follow will get some knowledge for free, while the first mover has to spend more resources on learning how to use new technologies efficiently. So this would speak against a first-mover advantage. If other countries adopt more stringent mitigation policies in the future, a country that has already spent resources on developing new technology could export that technology, at least for a while until newer technology is developed. If there are increasing returns for research, this could also go both ways, when thinking about a first-mover advantage, depending on whether or not it is possible to appropriate the value of the earlier research when newer technology is developed. If the new technology requires existing, already patented technology, the owners of those patents will benefit. If the new technology does not use the earlier developments directly but benefits more indirectly, then this will go against a first-mover advantage since the newer technology will be cheaper to develop.

The example of Japanese investment in Photovoltaic technology

Watanabe et al (2002) discuss the case of Japanese investment in Photovoltaic (PV) technology, that is, solar cells for electricity generation. The policy is described as very successful. Since Japan is a mid-latitude country, there are other countries where PV technology can deliver much more electricity. However, by finding a type of technology that fits well with the existing technological know-how in the country, and that generates positive spillovers on other industries in the country, they were able to create momentum for the technology. This started virtuous cycles that made the technology cheaper to produce and use, which increased the volume, which further decreased costs and so on. So the policy helped start the virtuous cycles, but once they got started, they gained a momentum of their own.

As well as probably being a good policy, even without any considerations of climate change, this can be seen as a successful example of a country using policy to direct resources towards research on a technology that fits the country well, from a state of knowledge perspective, but that not necessarily is the best technology for reducing domestic emissions. These efforts led to the improvement of a technology that is likely to reduce the costs of other countries' climate-change mitigation efforts significantly.

Conclusions about technology

Putting a price on greenhouse gas emissions will stimulate research on, and the use of, abatement technology. If there were no market failures in the process of technological change, and if emis-

sions were priced globally, no specific policies aimed at technological change would be required. There do, however, seem to be market failures such as positive externalities and informational problems which warrant additional policy interventions. Despite this, there is some scepticism among economists about using policy instruments to correct for these market failures, since it is difficult to implement good policies that affect the direction of technological change, while still leaving as much as possible of the decision-making to those best informed about the different alternatives.

If aiming to develop technology that can be exported profitably or that can help other countries reduce their emissions at lower cost, pricing emissions unilaterally in a country is not likely to deliver this, and the case for additional policy interventions is strengthened.

5

Chapter 5

Leadership in negotiations

Many of the rules for dealing with climate change are set in interstate negotiations, be it the European Union or global institutions. A country that is able to affect the outcome of these negotiations can have a significant effect on global emissions of greenhouse gases. The ability to influence the outcome of these negotiations does, in part, depend on other aspects of a country's climate-change mitigation policy.

Within the research field of international affairs, it is widely assumed that leadership is a prerequisite, although not sufficient on its own, to reach an agreement in institutional negotiations. The literature speaks about three different types of leadership: structural; idea-based; and directional leadership (Karlsson et al, 2011; Parker & Karlsson, 2010; Kanie, 2003; Young, 1991). These are all important, and ideally, all three forms are present during a process. However, one party does not necessarily exercise all three (Young, 1991).

I would like to thank Daniel Engström Stenson for his help with the writing of this section.

Structural leadership is mainly applicable to major powers, able to influence negotiations by putting pressure on other states and thereby trying to change the pay-offs associated with different outcomes, through issue linkages, sticks and carrots. Idea-based (also called instrumental or entrepreneurial) leadership refers to the ability to come up with a policy proposal during the actual negotiations, thereby finding common ground for agreement. Directional leadership rests on taking unilateral action and is accomplished by the demonstrated effect of leading by example. Hence, the latter is the leadership most applicable to this study, and is also the one, together with idea-based leadership — the two are sometimes strongly interconnected — that seems possible for Sweden to exercise.

Climate negotiations are believed to be particularly suitable for directional leadership, because of its complexity and the fear of competitive disadvantages when acting alone. By making a first move, leaders provide a model that others may want to emulate, which proves that leadership is about acting, not talking (Karlsson et al, 2011). However, it also emphasizes that in order to exercise effective directional leadership, the perceived leader has to stand by their word and live up to their commitments; for instance, EU commitments under the Kyoto Protocol (Parker & Karlsson, 2010). It has also been argued that in order to build credibility, actions have to include some form of 'sacrifice', meaning that if emission reductions are made without effort, the credibility gains are smaller (Skodvin & Andresen, 2006). One example would be if that the EU would achieve its emission target through the extensive use of off-sets (Parker & Karlsson, 2010).

The possibility of improving the chances of international

agreement, by exercising directional leadership, has at least two interesting and important aspects that are worth discussing here. Firstly, taking on the role as a leader in the negotiations is not dependent on the size of the country. Alone, or in coalition with other medium-sized states, a smaller country can have a large impact on negotiations (Schreurs & Tiberghien, 2007). It may even, in some cases, be an advantage to be a smaller country (Kanie, 2007). Secondly, credibility and legitimacy is imperative for effective leadership (Karlsson et al, 2011). This means that one consideration going into the formulation of the countries mitigation policy could be to build credibility.

International negotiations can be a way of influencing agreements to regulate carbon emissions, and also be a venue for a country to promote a technology developed within that country, or to find a larger market for its existing technology.

History shows several cases where single states, or groups of states, have played major roles in reaching an agreement on environmental regulation.

During the negotiations leading to the Montreal Protocol, regulating the emission of ozone-depleting gases, the technological advancement in the US, greatly influenced the US to take an active role in the negotiations. This, in turn, led to an agreement to cut emissions, creating a larger market for American technology (Wettestad, 2002; Sebenius, 1991; Sprinz &Vaahtoranta, 1994).

Along the same lines, Sweden and other Nordic countries, owing to their vulnerability, early on developed technology to deal with acid rain and became a driving force in the negotiations leading up to the Helsinki Agreement (Wettestad, 2002).

Kanie (2007) has studied the role that the Netherlands played during the climate-change negotiations leading up to the Kyoto Protocol. The conclusion is that the country had a disproportionately large impact on the negotiations given the size of the country. According to Kanie, one important factor behind this was that the Netherlands had decided unilaterally on an ambitious mitigation policy and, thereby, showed directional leadership, so that there was national agreement among major parties, such as politicians, NGOs and businesses on this policy.

Skodvin and Andresen (2006) argue that leadership is hard to distinguish from traditional bargaining and that it might be overemphasized in many studies. In their view, what is believed to be a sign of leadership is, in many cases, actions made by people to promote their own interests. Their study argues that the EU decision to go on with the Kyoto Protocol even after the US dropped out, was not an effort to position itself as a directional leader, but rather a result of the EU's need to position itself as a foreign policy actor in a field left open. They also argue that the actions pursued by the EU would have been made regardless of the existence of the Kyoto Protocol. The former argument is supported by Schreurs and Tiberghien (2007). It has also been argued that the major role played by the EU in the process leading up to the protocol's ratification was its negotiations with Russia on the accession process to the World Trade Organization (Parker & Karlsson, 2010). In that case, the Russian ratification of the Kyoto Protocol was a result of the EU's structural leadership rather than directional or idea-based leadership.

Generally, the literature seems to indicate that smaller countries can have a disproportionately large influence on the

outcome of global climate-change policy negotiations. Leading by example through domestic regulation, commitments (that are fulfilled) and technological advancements seem to be important aspects for being able to act as a credible leader in negotiations.

This would lead to the conclusion that Sweden has the possibility to act as a leader, with a reasonable chance of having an impact.

Since 1990, Sweden has, through strict environmental regulation and carbon pricing, reduced its emissions by 17%, along with maintained economic growth (Naturvårdsverket, 2011). Sweden has a 40% national target for emission reductions by 2020; significantly higher than most other states. Sweden also has a reputation of being a leader on environmental issues, which is important for its credibility (Marshall, 2007; Schreurs & Tiberghien, 2007).

Another important aspect of Sweden's possible leadership is its membership of the European Union. The EU is, according to a study by Karlsson et al (2011), the party within global climate negotiations that is perceived as a leader by the largest share of different actors (other state representatives, media, NGOs, business etc.). In particular, the EU is seen as a leader when it comes to mitigation actions and striving for future agreement (Karlsson et al, 2011).

The EU has also been a forerunner in its introduction of a regional market for emissions trading, the EU-ETS, which stands largely as a model for many other similar emission-trading schemes (Parker & Karlsson, 2010).

So, perhaps Sweden's best way of affecting the outcome of international negotiations is to first try to affect the negotiations within the EU. Sweden is, for example, one of the countries

arguing that the EU should aim for a 30% reduction emissions target by 2020, rather than the current 20% target (Carlgren, 2011).

6

Chapter 6

Summary & discussion

For almost all countries, including Sweden, the only way to affect the global greenhouse gas emissions significantly is by trying to influence what other countries are doing. So, if moving ahead with a climate-change mitigation policy, the efforts should be aimed primarily at affecting what others do, rather than trying to achieve the largest possible direct emission reductions.

Past experience, trying to reach international agreement regarding emission reductions, suggests that this is not an easy task. Therefore, moving ahead successfully will likely require a carefully thought out strategy where different components are combined. These include trying to demonstrate that emission reductions can be made at a lower cost than expected, developing technologies or policy tools that help reduce the costs of reducing emissions, and trying to exercise leadership in international negotiations. When considering a strategy for moving ahead, it should be recognized that almost all countries are small in most respects. Therefore, efforts should be aimed at areas where a particular country can reasonably expect to have some effect.

By reducing emissions at a reasonable cost, a country could set an example by showing that this is possible and this could

make other countries more inclined to make emission reductions. However, before setting this as a goal for moving ahead, the country should be reasonably sure that it can, in fact, make the reductions at a low cost. In order to lower someone's expectations about the costs of emission reductions, the cost must be low compared to prior expectations. If the costs turn out to be higher than expected, the effect will be the opposite. Achieving the goal will also probably take a lot of time. Before it can have any effect on expectations, enough time must pass to first make the emission reductions happen and then allow for the evaluation of the costs.

For the case of Sweden, large emission reductions have already been made without any apparent costs in terms of GDP. So, it seems that carefully evaluating the past experience of the emission reductions in Sweden should be a prioritized first step. These results should then be communicated, to show that the emission reductions were, in fact, made at a reasonable cost without too much leakage.

A different component of moving ahead is to try to reduce the actual costs for other countries of reducing emissions. This can be done by developing, or demonstrating how to use, abatement technology. Developing new technology is costly. A small country does not generally have the resources to move the world technology frontier very far. It seems more realistic to try to perhaps find a narrow, technological niche where the country can be expected to have good prospects of successful research, and try to channel resources into such research. The resources can either be domestic investments or investments by foreign investors, which a country can attract by building attractive research environments.

As argued above, taking on more stringent emission targets unilaterally is not likely to, of itself, induce the kind of research sought here. Instead, policy instruments targeted at stimulating the desired research are needed. However, these policy instruments are difficult to use and there are many potential pitfalls. In addition to stimulating research on particular technologies, there is also a need for policies aimed at overcoming barriers to the adoption of technologies for reducing emission that seem to be possible at low, or even negative, cost. Thus, there is a need for good policy models that can be used for these purposes. A different type of contribution to reducing the costs of emission reduction is to develop such policy models. The development of policy models requires less physical resources and may, therefore, be more feasible for small countries.

A promising way to have an effect on global emissions is through leadership in negotiations, where there seems to be potential for significant influence, even for a relatively small country. However, one needs to keep in mind that the single most important obstacle before reaching a global deal is to get the US and China on board. For this, EU leadership will be important, but the domestic development in, and relations between, the US and China, will always play an important role.

What is the role of targets for direct emission reductions in a strategy for moving ahead? Adopting more stringent targets for domestic emissions should have some effects on the invention and adoption of abatement technology within the country. However, these effects may be small and may also fail to contribute to the development of the technologies that have the largest potential to affect global emissions by spreading to other countries. There

also seems to be some risk of carbon leakage and production could move to countries with more emission-intensive production. Furthermore, emission reductions of the same order of magnitude as Swedish emissions do not have any significant effect on climate.

Therefore, it seems that direct emission reductions should perhaps be seen as a tool rather than a goal in itself. The choice of emission targets can signal a number of things. It can indicate a country taking its responsibility to deal with climate change seriously, which could affect other countries' perception of the problem and, more importantly, affect its ability to exercise leadership in international negotiations. It can also signal a belief in the possibility of making emission reductions.

If emission reductions are used as a signalling tool, it matters if the reductions are made domestically or by financing reductions elsewhere. It seems that it is possible for Sweden to make significantly cheaper emission reductions by financing reductions elsewhere, compared to making them domestically. It should be remembered, however, that even if Sweden has relatively small per capita emissions, they are still much higher than long-term sustainable emissions. Furthermore, financing emission reductions in other countries is not a viable option for significant global reductions. When deciding on what type of emission reductions to make, the signal sent by making different choices must be considered, and the efficiency of different types of emission reductions should be judged on the total effect that they have in a strategy for moving ahead.

Given the urgency of the climate change issue, mitigation policy must be pragmatic. Resources spent on mitigation should be spent in the most efficient manner possible. The difficult thing

is to know what that means in practice. A country that considers moving ahead with mitigation policy needs a long-term strategy for achieving its goals. Each component of this strategy must then be evaluated against whether it will help to reach the ultimate goals that are set, or not.

7

Chapter 7

Comments

Martina Kruger,
Head of Climate and Energy Campaign for Greenpeace Nordic

Climate change, spiking fuel prices, energy risks and resource constraints mean that »business as usual« is neither an option for the global, European nor Swedish economies.

But in international discussions on climate targets and responsibilities we mostly hear two recurring arguments against taking a leading role. The first is that European and Swedish companies would have a competitive disadvantage compared to those that have not adopted progressive climate targets. The second is that even if Sweden and Europe would take on a leadership role, this would not help because »alone« we can not save the climate. Climate negotiations have stalled since the Copenhagen meeting and all parties are blaming each other while everyone waits for the other parties to act first. Meanwhile, the window of opportunity for a safe landing path for emission reductions is getting smaller. But as »Moving ahead« shows, there are good reasons to believe that smaller countries can actually influence a process in the right direction by taking on a leadership role.

Europe and Sweden, with very good preconditions, should now go forward and take on the responsibility to show that it is possible to make the transition to climate-friendly and sustainable production and that this will not only be good for the environment but also favour a green economy. This can and will inspire other countries and regions and create new dynamics in the international climate negotiations. However, for far too long European business organisations have been dominated by the dinosaurs in their middle holding them back and missing out on the economic opportunities that would come from a cleaner and greener economy. As a result, there are still policies that protect the polluters. For instance, European steel companies – thanks to the efforts of steel sector lobbyists – currently hold €3.4 billion in surplus emission allowances, under the EU's emissions trading scheme and make »windfall profits« by passing on the price of emission allowances (originally granted to the companies for free) to the buyers of steel. This has been granted to them because of the fear of »carbon leakage« which Johan Gars also describes in the report. This cannot continue.

To support private investments in green products, services and infrastructure, Europe needs policies that are not held back by overprotection of old business models at the expense of innovative industries and sectors.

First and foremost, this requires the EU to update its 2020 climate policies. The current 20% EU climate target for 2020 does not provide an incentive for clean investment. The amount of unused emission allowances in the EU's ETS means there is little reward for efficiency, action and innovation. Only a more ambitious target – of 30% domestic emission reductions by 2020

(compared to 1990 levels) – can deliver green jobs and a resource-efficient economy that can compete on the global stage.

Updating the EU's 2020 climate target to at least 30% domestically is a policy for higher investments, a greener economy, reduced climate risk, jobs and energy security. It is time for businesses to speak out and become climate leaders, signalling to governments that the business community embraces progressive change. Greenpeace has been calling on businesses in the EU to speak out in favour of innovation and green growth and to support a domestic, unconditional 30% emission cut by 2020, compared to 1990 levels. This should be a first step towards a 40% emission target for all developed countries for 2020, consistent with keeping global temperature increases well below two degrees Celsius and avoiding the catastrophic effects of climate change. Under their EU presidency in 2009 Sweden has launched the idea of transiting towards an eco-efficient economy. There is no time to lose.

If I could have wished for an additional aspect to be investigated in this study of gains and losses of moving ahead with climate change, it would have been to look at the way the cost estimates are made. There is evidence that the costs of environmental measures are often overestimated while the gains are underestimated. A systematic look at the literature around this aspect would have made a welcome contribution to this debate.

Eva Samakovlis
Head of Environmental Economics Research,
National Institute of Economic Research

Swedish environmental and climate policy has often been focused on "moving ahead". For example, Sweden has a target to reduce greenhouse gas emissions by 40% compared to 1990. This is the most ambitious target within the EU, and means that Sweden aims to reduce its emissions by 15 percentage points more than demanded. One reason behind this is to exemplify the possibility of combining an offensive climate policy with high economic growth. Sweden has been able to show that over time it is possible to decouple growth from emissions. The climate policy is one reason for this, but so is the development of nuclear power, biofuel-based district heating and the supply of hydro-power (National Institute of Economic Research, 2011).

In this report, Johan Gars and FORES discuss the important question of how we are to move ahead and what revenues could follow from such a strategy. It should be obvious that big political decisions need to be preceded by sound economical analysis that makes the costs and revenues from such a strategy visible. This is, however, too rare when it comes to decisions in environmental politics, and has not been done in the case of the Swedish decision to move ahead. Given that a decision on moving ahead has been taken, it is important to discuss how this moving ahead is to be done. The Swedish moving ahead strategy has so far been primarily focused towards reducing national carbon emissions more than requested by international agreements. This high level of ambition has led to the introduction of different types of policy measures

to reduce emissions. Some measures are more successful than others, and in certain areas there are simply too many measures. The high level of ambition has also led to high costs for further emission reductions in Sweden. But to move ahead can also mean increased investments in emission reducing measures abroad, or to invest in research and development, or to share successful economic measures from the national policy to other countries. In the case of Sweden, which emits only a very small share of global emissions, a move ahead strategy aiming at influencing other nations' emissions may be more efficient.

To justify a moving ahead policy, the stimulation of technical development within Swedish businesses, increased competitiveness, new opportunities for employment and a strengthened possibility to be pushers in the international climate negotiations are highlighted as the main arguments (SOU 2008:23, Prop. 2008/09:162). These arguments, technological advancement, competitiveness, employment, and negotiations, will be discussed below. Linked to each and every one of these arguments is a comprehensive economic literature that the author aims to condense. I largely agree with the conclusions in this report regarding which arguments might generate revenues.

The report points out the negotiations as the primary argument for moving ahead. The negotiations argument is based on the assumption that if Sweden, by moving ahead, can influence other countries' climate policy ambitions, the aggregated effects can be very positive. According to the author, the literature supports that small countries may have a large influence on the outcome of global climate negotiations. Whether this also goes for Sweden has not been analysed, and I believe there is need for a thorough inves-

tigation to see how Sweden's actions have influenced the actions of other countries during climate negotiations. This is obviously difficult, but at the same it is pressing to describe its effects since an ambitious climate policy is linked with economic costs.

The technological advancement argument takes its stance in the assumption that an ambitious climate policy, in the form of higher costs for emissions, creates incentives for a development of green technology that may be spread to other countries. Even though it is correct that the carbon tax creates incentives for technological development, it is unclear to what extent unilateral tax rises, from already high levels, will be able to further push the technological development. Businesses engaged in research and development are driven by profit incentives, rather than the level of the carbon tax. Research and development, which is obviously an important part in an efficient climate policy, is better stimulated by other measures. Several studies have shown that the costs for reducing carbon emissions are decreased when measures that create a price on carbon is supplemented by support measures. This is because two so-called market failures occur, and that measures taken to address one of them only partly solves the other.

The competitiveness argument is constituted by the so-called Porter Hypothesis, which says that stringent and correctly designed environmental regulation, leads to innovations and savings that increase competitiveness. Hence, the hypothesis says that the costs emerging from the environmental policy, in the form of taxes or investments, are smaller than the positive effects that follow from increased competitiveness. The study refers to the literature overview in Brännlund (2007), in which the conclusion is drawn that it is not possible to prove a general Porter effect, and

that the Porter Hypothesis until further notice may be rejected. Several studies have had difficulties measuring the regulations and have been undertaken in countries where economic measures, which the Porter Hypothesis relates to, are unusual. The Swedish National Institute of Economic Research has recently tried the hypothesis with a new approach, analysing the impact of environmental protection investments on the productivity of Sweden's manufacturing industry, and whether investments in pollution treatment affect productivity differently compared to investments in pollution prevention (National Institute of Economic Research, 2010). Also in this analysis, the Porter Hypothesis is rejected.

That the climate policy creates jobs, the so-called employment argument, is often present in the debate on moving ahead, but is not dealt with in this report. Among economists there is, however, a broad consensus that the long-term net effects on employment from an increased level of ambition in the climate policy are small. The changes in relative prices on goods and services that follow an increased carbon tax will shift demand towards consumption of goods and services that lead to lesser carbon emissions. Hence, some sectors and regions will gain, while others will suffer from this policy. Also this argument can then be rejected.

The indirect costs from moving ahead, in terms of carbon leakage, are discussed in detail in this report, while direct costs are mentioned less. Carbon leakage means that if Sweden unilaterally drives an ambitious climate policy there is a risk that businesses will move their production to countries that lack constraints on emissions, and that emissions as a consequence will increase. As the author correctly mentions, analyses have shown that this risk is often exaggerated, since carbon taxing is just one of many

factors to take into consideration when businesses decide on where to locate. When it comes to direct costs the author of this report believes that large emission reductions have been made in Sweden, without any visible cost in terms of GDP. It is unclear what the author means by that and what implications he believes this has for the moving ahead strategy. The report refers to Eklund (2009), who estimates the costs from reducing Sweden's emission by another 20% to 30 billion SEK a year. To move ahead is, in other words, linked to costs. From a moving ahead perspective it is interesting to compare these costs to the grants for public financed research on climate and energy, which during 2005–2008 amounted to SEK 1.2 billion annually. A shift in the moving ahead strategy, away from more ambitious domestic emission reductions could potentially lead to significantly larger investments in research and development. How to design a sound policy for climate-related research and technological development, however, involves many complicated issues. Alfsen and Eskeland (2007) discuss how such a policy may best be designed.

Further, the author of this report believes that more ambitious emissions targets may function as a tool to get other countries to follow, rather than be a goal in itself. I believe that Sweden has already shown that it is possible to move ahead. Today Sweden has the second lowest emissions per GDP-unity. Several analyses have shown that the costs from Sweden's climate policy exclusively depend on the share of emission reductions undertaken domestically (Carlén 2007, Carlén and Frykblom 2008, National Institute of Economic Research 2008, Brännlund and Kriström 2010). In order for a cost-efficient policy, it is therefore crucial that Sweden, to as large an extent as possible, gets to credit invest-

ments in emission reducing projects abroad. The author, however, does not believe that funding of emission reductions abroad is a practicable way forward. My opinion is that investments in emission reductions abroad, through the flexible mechanisms of the Kyoto Protocol, can constitute an important supplement to national measures and be part of Sweden's strategy for moving ahead. However, it is important that the mechanisms for the investments are reviewed and improved so that emission reductions are secured. It is important to emphasise that these mechanisms cannot replace national emission reductions. Emissions in Sweden have to decrease as well, if we are to reach the two-degree target.

Decision-makers have to consider whether the most efficient strategy for moving ahead really consists of further emission reductions within Sweden, or if it is more important to strive towards finding solutions to make emission reductions cheaper. This report by Johan Gars and FORES will hopefully make an important contribution to such a discussion.

References

Acemoglu, D., Aghion, P., Bursztyn, L. & Hemous, D. (2011) *The environment and directed technical change*, American Economic Review [in press].

Aldy, J.E., Krupnick, A.J., Newell, R.G., Parry, I.W.H.,& Pizer, W.A. (2010) *Designing climate mitigation policy*, Journal of Economic Literature,, 48 (4), 903- 934.

Alfsen, K.H. & Eskeland, G.S. (2007) *A broader palette: The role of technology in climate policy*, Rapport till Expert-gruppen för miljöstudier.

Antweiler, W., Copeland, B.R. & Taylor, M.S. (2001) *Is free trade good for the environment?* American Economic Review 91 (4), 877-908.

Brännlund, R. (2007) *Miljöpolitik utan kostnader? En kritisk granskning av Porterhy-potesen*, Rapport till Expertgruppen för miljöstudier.

Brännlund, R. and B. Kriström (2010): *En effektiv klimat-politik*. SNS Förlag.

Brunnermeier, B.S. & Levinson, A. (2004) *Examining the evidence on environmental regulations and industry location.* Journal of Environment Development;

Carlén, B. (2007) *Sveriges klimatpolitik: Värdet av utsläpp-shandel och valet av målformulering,* Rapport till Expert-gruppen för miljöstudier.

Carlén, B. and P. Frykblom (2008): *Kostnader för olika ambitionsnivåer i svensk klimatpolitik – betydelsen av att övriga sektorn deltar i internationell utsläppshandel.* Pm till Expert-gruppen för miljöstudier.

Carlgren, A. (2011) *Seven governments agree to join push for target of 30% cuts in greenhouse gas emissions by 2020, The Guardian, 14 March, 2011.* [online] Available from: http://www.sweden.gov.se/sb/d/12047/a/162969 (Accessed 2011-06-07)

Carlsson-Kanyama, A., Getachew, A. Peters, G. & Wadeskog, A. (2007) *Koldioxidutsläpp till följd av Sveriges import och konsumtion: Beräkningar med olika metoder*, KTH, TRITA-IM.

Climate Analysis Indicators Tool CAIT (2011) [online] Available from: http://cait.wri.org/ [Accessed June 2011].

Copeland, B.R. & Taylor, M.S. (2004) *Trade growth and the environment*, Journal of Economic Literature, 42 (1), 7-71.

Dietzenbacher, E. & Mukhopadhyay, K. (2007) *An empirical examination of the pollution haven hypothesis for India: Towards a green Leontief Paradox?* Environmental & Resource Economics, 36, 427-449.

Di Maria, C. & Smulders, S.A. (2004) *Trade pessimists vs technology optimists: Induced technical change and pollution havens Advances in Economic Analysis & Policy*, 3 (2), Article7.

Di Maria, C. & van der Werf, E. (2008) *Carbon leakage revisited: Unilateral climate policy with directed technincal change,* Environmental & Resource Economics, 39 (2), 55-74.

Edenhofer, O., Bauer, N. & Kriegler, E. (2005) *The impact of technological change on climate protection and welfare: Insights from the model MIND,* Ecological Economics, 54, 277-292.

Ederington. J., Levinson. A. & Minier, J. (2003) *Footloose and pollution-free',* NBER Working Paper #W9718.

Eklund, K. (2009) *Vårt klimat: Ekonomi, politik, energi*, Stockholm, Nordstedts akademiska.

Energieffektiviseringsutredningen (2008) *Ett energieffektivare Sverige*, SOU 25

Enkvist, P.-A., Nauclér, T. & Rosander, J. (2007) *A cost curve for greenhouse gas reduction,* The McKinsey Quarterly, 1.

European Commission (2011) *A roadmap for moving to a competitive low carbon economy in 2050*. Access through http://ec.europa.eu/clima/documentation/roadmap/docs/com_2011_112_en.pdf

Fischer, C. & Newell, R.G. (2008) *Environmental and technology policies for climate mitigation,* Journal of Environmental Economics and Management, 55,142-162.

Golombek, R. & Hoel, M. (2004) Unilateral emission reductions and cross-country technology spillovers, Advances in Economic Analysis & Policy, 4 (2), Article 3.

Graichen, V., Schumacher, K., Matthes, F.C., Mohr, L., Duscha, V., Schleich, J. & Dienkmann, J. (2008) Impacts of the EU Emissions Trading Scheme on the industrial competitiveness in Germany, Environmental Research of the Federal Ministry of the Environment, Nature Conservation and Nuclear Safety, Research Report 3707 41 501, UBA-FB 001177.

Greaker, M. (2006) Spillovers in the development of new pollution abatement technology: A new look at the Porter Hypothesis, Journal of Environmental Economics and Management, 52, 411-420.

Greenstone, M. (2002) The impacts of environmental regulations on industrial activity: Evidence from the 1970 and 1977 Clean Air Act Amendments and the Census of Manufactures, Journal of Political Economy, Dec,110 (6), 1175-1219.

Hourcade, J.-C., Demailly, D., Neuhoff, K. & Sato, M. (2007) Differentiation and dynamics of EU-ETS industrial competitiveness impacts, Climate Strategies

International Energy Agency (**IEA**) (2008a) Issues behind competitiveness and carbon leakage, IEA Information Paper, October.

International Energy Agency (**IEA**) (2008b) Climate policy and carbon leakage impacts of the European Emissions Trading Scheme on aluminium, IEA Information Paper, October.

International Energy Agency (**IEA**) (2007) Climate Policy Uncertainty and Investment Risk [Online] Available at http://www.iea.org/w/bookshop/add.aspx?id=305

Jaffe, A.B., Newell, R.G. & Stavins, R.N. (2005) A tale of two market failures: Technology and environmental policy, Ecological Economics, 54 (2-3), 164-174.

Jaffe, A.B., Newell, R.G. & Stavins, R.N. (2003) Technological change and the environment. In: K-G Mäler, K.-G. & Vincent, J.R. (eds.), Handbook of environmental economics, Volume 1, Amsterdam: Elsevier, pp. 461-516.

Jaffe, A.B., Newell, R.G. & Stavins, (2002) Environmental policy and technological change, Environmental and Resource Economics, 22 (1-2), 41-70.

Jaffe, A.B. & Palmer, K. (1997) Environmental regulation and innovation: A panel data study, Review of Economics and Statistics,79 (4),610-619.

Jaffe, A.B., Peterson, S.R., Portney, P.R. & Stavins, R.N. (1995) Environmental regulation and the competitiveness of US manufacturing: What does the evidence tell us? Journal of Economic Literature, 33 (1),132-163.

Kanie, N. (2007) Middle power leadership in the climate change negotiations: Foreign policy of the Netherlands. In: Harris, P.G. (ed.) Europe and global climate change (2007) Cheltenham: Edward Edgar Publishing Limited 87-113.

Karlsson, A., Parker, C., Hjerpe, M. & Linnér, B.-O. (2011) Looking for leaders: Perceptions of climate change leadership among climate change negotiation participants, Global Environmental Politics, 11 (1) 89-107

Lanjouw, J.O. & Mody, A. (1996) Innovation and the international diffusion of environmentally responsive technology, Research Policy, 25 (4), 549-571.

Levinson, A. & Taylor, M.S. (2008) Unmasking the pollution haven effect, International Economic Review, 49 (1)

Marshall, K.E. (2007) Sweden, climate change and the EU context. In: Harris, P.G. (ed.) Europe and global climate change Cheltenham: Edward Edgar Publishing Limited 139-161

McDonald, A. & Schrattenholzer, L. (2000) Learning rates for energy technologies, Energy Policy, 29, 255-261.

McKinsey (2008) Möjligheter och kostnader för att reducera växthusgasutsläpp I Sverige

National Institute of Economic Research (2008): *En samhällsekonomisk granskning av Klimatberedningens handlingsplan för svensk klimatpolitik*. Specialstudie Nr 18.

National Institute of Economic Research (2010): *Does environmental leadership pay off for Swedish industry? – Analyzing the effects of environmental investments on efficiency*, Working paper No 119.

National Institute of Economic Research (2011): *Klimatpolitikens utmaningar under mandatperioden*. Specialstudie Nr 25.

Naturvårdsverket (2011) [Online] Available from: http://www.naturvardsverket.se/sv/Start/Klimat/Utslapp-av-vaxthusgaser/Statistik-och-trender/Utslappstrender/ [Accessed June 2011].

Newell, R.G. (2009) international climate change technology strategies. In: Aldy, J.E. & Stavins, R.N (Etd). Post-Kyoto international climate policy: Implementing architectures for agreement, Cambridge: Cambridge University Press, 403-439

Nilsson, C. (1999) A unilateral versus a multilateral carbon dioxide tax: A numerical analysis with the European model GEM-E3. Working Paper no. 66, Konjunkturinstitutet.

OECD (2009) The economics of climate change mitigation: Policies and options for global action beyond 2012. [Online] Available at: http://www.oecd.org/document/56/0,3746,en_2649_34361_43705336_1_1_1_1,00.html

Parker, C.F. & Karlsson, C. (2010) Climate change and the European Union's leadership moment: An inconvenient truth? Journal of Common Market Studies, 48(4) 923-43.

Peters, G.P., Minx, J.C., Weber, C.L. & Edenhofer, O. (2011) Growth in emission transfers via international trade from 1990 to 2008. PNAS, 108, 8903-8908.

Popp. D. (2005) Uncertain R&D and the Porter Hypothesis. Contributions to Economic Analysis & Policy, 4 (1), Article 6

Popp. D. (2004) ENTICE: Endogenous technological change in the DICE model of global warming, Journal of Environmental Economics and Management, 48 (1), 742-768.

Popp. D. (2002) Induced innovation and energy prices, American Economic Review, 92 (1),160-180.

Porter, M.E. & van der Linde, C. (1995) Toward a new conception of the environment-competitiveness relationship, Journal of Economic Perspectives, 9 (4), 97-118.

Prop. 2008/09:162 *En sammanhållen klimat- och energipolitik – Klimat.*

Samakovlis, E. (2011) Klimatpolitikens utmaningar under mandatperioden, Specialstudier nr 25, Konjunkturinstitutet.

Schreurs, M.A. & Tiberghien, Y. (2007) Multi-level reinforcement: Explaining European Union leadership in climate change mitigation', Global Environmental Politics, November, 7 (4) 19-46.

Sebenius, J. (1991) designing negotiations toward a new regime: The case of global warming, International Security, 15 (4) (spring), 110-148.

Sinn, H.-W.(2008) Public policies against global warming: a supply side approach, International Tax and Public Finance, 15, 360-394.

Skodvin, T. & Andresen, S. (2006) Leadership revisited. Global Environmental Politics, 6 (3) 13-27.

SOU 2008:24, *Svensk klimatpolitik*, Betänkande av klimatberedningen.

Sprinz, D.F. & Vaahtoranta, T. (1994) The interest-based explanation of international environmental policy. International Organization, 48 (1), 77-105.

Stern, N. (2006) The Stern Review on the economics of climate change. [Online] Available at: http://webarchive.nationalarchives.gov.uk/+/http://www.hm-treasury.gov.uk/stern_review_report.htm

Sterner, T. (2003) Policy instruments for environmental and natural resource management, Washington DC: Resources for the Future

Söderholm, P. & Hammar, H. (2005) Kostnadseffektiva styrmedel i den svenska klimat- och energipolitiken? Metodologiska frågeställningar och empiriska frågeställningar', Konjunkturinstitutet Specialstudie Nr 8, November.

Vollebergh, H.R.J. (2007) Differential impact of environmental policy instruments on technological change: A review of the empirical literature, Tinbergen Institute Discussion Paper, TI 2007-042/3.

Watanabe, C., Griffy-Brown, C., Zhu, B. & Nagamatsu, A. (2002) Inter-firm technology spillover and the 'virtuous cycle' of photovoltais development in Japan. In Grübler, A. Nakicenovic, A. & Nordhaus, W.D. Technological change and the environment, Washington, DC: Resources for the Future.

Wettestad, J. (2002) The Vienna Convention and Montreal Protocol on ozone-layer depletion. In: Miles, E.L., Underdal, A. et al (eds.), Explaining regime effectiveness: confronting theory with evidence, Cambridge, MA: MIT Press, pp. 149-170.

Young, O. (1991) Political leadership and regime formation: on the development of institutions in international society. International Organization, 45 (3) (Summer),281-308.

No single state is able to solve the problem of climate change alone – certainly not Sweden, with less than 0.2% of global emissions. Therefore, if the aim of a nation such as Sweden is to reduce global emissions in significant numbers, it is necessary to find ways to influence other countries to reduce their emissions as well. This study aims to investigate the possibilities and risks when moving ahead.

If a country moves ahead on climate policies this is beneficial for the climate and, in some cases, also for the country's economy. The benefits are through technological spillovers, within the country and to other countries, but also as a social and economic example for their countries and to reinforce the credibility of the country in international negotiations. There are costs associated with moving ahead and there is evidence of carbon leakage, production moving to pollution havens. However the empirical evidence also shows that the magnitude of this leakage is insignificant. Moving ahead can be made through carbon pricing but may also be complemented by public support to infrastructure and research support, preferably concentrated in specific areas for maximum effect.