CLIMATE POLICY, THE STATE, AND THE PROBLEM OF CREDIBLE COMMITMENT

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Zusammenfassung

Diese Arbeit untersucht Ursache und Wirkung der Rechtsunsicherheit, die von dem Problem der glaubwürdigen Selbstbindung in der Klimapolitik ausgeht. Der Staat definiert und verteilt Eigentumsrechte in einem Umfeld, in dem Verträge nicht durch eine unabhängige Instanz durchgesetzt werden können. In einem solchen Umfeld ist es unerlässlich, dass sich der Staat glaubwürdig an die Aufrechterhaltung der Eigentumsrechte bindet, um Investitionen zu ermöglichen. Die Arbeit besteht aus vier unabhängigen Publikationen und einem einleitenden und einem abschließenden Kapitel.

Kapitel 1 führt ein in Forschungsumfeld und -fragen und die grundlegenden Konzepte der Neuen Institutionenökonomie, einer Disziplin die den theoretischen Rahmen der Dissertation liefert. Kapitel 2 stellt die verschiedenen rechtlichen Stellschrauben inländischer Handelssysteme für Treibhausgasemissionen vor. Es wird argumentiert, dass Rechtsunsicherheit eine wichtige Quelle von Investitionsstau und Risikoprämien in Emissionsmärkten ist. In Kapitel 3 werden drei Quellen der Rechtsunsicherheit unterschieden: strategisches Verhalten zwischen Regulierer und Regulierten, Unsicherheit über die Kosten der Klimaschäden und die Kosten von Emissionsvermeidungen, und schließlich die Unsicherheit wechselnder politischer Präferenzen. Der soziale Nutzen glaubwürdiger Selbstbindung an langfristige Klimapolitik variiert je nach Quelle der Rechtsunsicherheit. Es werden verschiedene institutionelle Arrangements vorgestellt und miteinander verglichen, die es dem Staat erlauben Rechtsunsicherheit abzubauen. Kapitel 4 formalisiert ein institutionelles Arrangement, die Anpassungsregel, in einem spieltheoretischen Rahmen und bewertet deren sozialen Nutzen im Vergleich zur Bindung an ein festes Politikziel. Kapitel 5 untersucht das Selbstbindungsproblem in der internationalen Klimafinanzierung und dessen Implikationen für Transaktionskosten bei zwischenstaatlichen Transfers. Die Ursachen von Transaktionskosten und deren Wirkung auf die optimale Balance zwischen inländischen und internationalen Vermeidungsleistungen werden aufgezeigt. Kapitel 6 schließt die Dissertation mit einer Diskussion der intellektuellen Grenzen einer institutionen-ökonomischen Sicht auf die Klimapolitik und deren Implikationen für das Verhältnis von Wissenschaft zu Politik.

Summary

This thesis explores the regulatory uncertainty that originates from the problem of credible commitment in climate policy. The state defines and transacts property rights in an environment where third-party enforcement, the possibility to have contracts enforced by an independent authority, is infeasible. In such a setting, the ability to credibly commit to the maintenance of established rights is essential if one wants to encourage other actors to cooperate. The thesis consists of four independent publications and an introductory and a concluding chapter to address these points.

Chapter 1 presents research context and questions and the thesis' conceptual framework. Chapter 2 reviews design elements for domestic cap-and-trade systems and finds that regulatory uncertainty is an important source of investment hold-up and risk in carbon markets. Chapter 3 explores three sources of regulatory uncertainty: strategic interaction between the state and regulated firms, uncertainty over the costs of climate change damages and emissions abatement, and changing political preferences. The social benefit of commitment to long-term climate policy varies depending on the source of regulatory uncertainty. The chapter also qualitatively compares different commitment devices the state could use to reduce regulatory uncertainty. Chapter 4 presents a formalisation of one commitment device, the adjustment rule, in a game theoretic context and assesses its social benefit in comparison to commitment to a fixed policy target. Chapter 5 explores the drivers and forms of transaction costs in international climate finance. It shows how transaction costs in state-to-state transfers invalidate the assumed separability of allocation and efficiency in economic assessments of global mitigation costs. Finally, Chapter 6 summarises the main messages of preceding chapters and concludes with a discussion of the limits of a new institutional view on climate policy and its implications for the science-policy interface.

Contents

1 Introduction ... 6

Research frame ... 8

A new institutional view on climate policy ... 11

2 Domestic Emission Trading Systems ... 20

Introduction ... 20

Rationale of emissions trading ... 20

Elementary design features of cap-and-trade ... 22

Key lessons from the EU ETS ... 32

Conclusions ... 39

3 Credible commitment in carbon policy ... 51

Introduction ... 51

Sources of credibility ... 52

Sources of regulatory uncertainty ... 54

Commitment devices ... 60

Conclusions ... 68

4 Commitment under uncertainty: an adjustment rule for climate policy ... 74

Introduction ... 74

A general formulation of time inconsistency and commitment ... 75

Commitment under uncertainty ... 78

Commitment to an adjustment rule ... 84

Commitment devices ... 85

Conclusions ... 87

5 The neglected side of global mitigation costs ... 90

Introduction ... 90

Climate finance as contracting problem ... 91

Drivers of transaction costs in international climate finance ... 93

Incidence of transaction costs in international climate finance ... 96

Conclusions ... 99

6 Conclusions ... 104

The efficiency-boundary of the state ... 104

The science-policy gap ... 107

Appendix ... 109

"Two neighbours may agree to drain a meadow, which they possess in common; because it is easy for them to know each others mind; and each must perceive, that the immediate consequence of his failing in his part, is, the abandoning the whole project. But it is very difficult, and indeed impossible, that a thousand persons should agree in any such action; it being difficult for them to concert so complicated a design, and still more difficult for them to execute it; while each seeks a pretext to free himself of the trouble and expence, and would lay the whole burden on others."

David Hume (1740: 538)

1 Introduction

Let us start with the general observation that uncertainty is pervasive in climate policy. It is pervasive not only because the complex dynamics of the Earth system limit our understanding of the global carbon cycle and its links to atmospheric concentrations of greenhouse gases, radiative forcing, warming, and physical impacts, but also because natural system uncertainty is aggravated by the manmade uncertainty of social systems. People develop technologies to manage their interactions with nature, and they agree on institutions to manage interactions among themselves. In David Hume's example (quoted above), two neighbours agree to manage a local common pool resource (*res communis*) because they can "know each others mind". With the size of social groups and resource pools, however, increase the cost of crafting and maintaining such agreements because information problems and institutional uncertainties amplify. These costs are usually termed 'transaction cost' in the economic literature although 'institutional cost' is also used at times. If they are too high, if they outweigh the benefit of carrying out a transaction in an orderly way, institutions and property rights remain incomplete. In our above example, this means that the 'tragedy of open access resources' (*res nullius*), that which belongs to no one because everyone claims it, unfolds its detrimental plot.

David Hume uses his example to highlight the role of the state in overcoming the transactional challenge that besets many environmental resource pools. Transaction costs

will form a significant part of global mitigation costs because the atmosphere is an open access resource whose transformation into a global common requires the definition and maintenance of property rights through long-term collective action among the largest group of people one could possibly think of. The state allows even a "thousands persons" (Hume) and more to act in common because the supreme authority entrusted in it creates the possibility to define and enforce property rights among very large numbers of individuals. And although civil society actors such as non-governmental organisations play an important role in facilitating global cooperation, the focus of this thesis lies on the role of the state because it is believed that it will remain the principal actor in climate policy in any timeframe that is relevant to the problem. Its unique features, however, give rise to a severe transactional hazard: the problem of credible commitment. Before I say more on its origins and forms, it is important to define three key concepts:

1.	**Institution**: formal or informal set of rules that guide human behaviour. (North 1990)
2.	**Property right**: Bundle of rights that establishes authority to make a free choice. (Ostrom 2000)
3.	**Transaction cost**: costs of establishing and maintaining property rights. (Allen 2000)

Table 1: Key concepts and their definitions

Why not a political Coase theorem?

The problem of credible commitment is the main reason why a political Coase theorem is at least as non-applicable as an economic Coase theorem (Acemoglu 2003). The economic Coase theorem maintains that, if property rights are well-defined and transaction costs zero, economic agents will contract to achieve an efficient outcome, regardless of the initial distribution of property rights among agents (Coase 1960, Stigler 1966).[1] It hence proclaims the separability of distribution and Pareto-efficient allocation. An extension of this reasoning to political transactions suggests a tendency toward institutions that achieve the best outcome for society irrespective of who has political power. Social groups controlling the state could contract with its subjects (citizens, firms) to enact institutions that maximise social welfare and then redistribute part of the gains to themselves. However, in political transactions widespread enforcement problems arise because a state that is "strong enough to protect property rights and enforce contracts is also strong enough to confiscate the

[1] It was not Ronald Coase but George Stigler who invented the theorem though Coase disagreed with having tied his name to this anti-institutional conjecture. See Coase retelling the episode in his own words (from minute 6:28) at www.youtube.com/watch?feature=endscreen&NR=1&v=GVjIB9b59ig

wealth of its citizens" (Weingast 1995: 1). The sovereign party to the transaction cannot be coerced to abide by the terms of the contract.

The political Coase theorem does not apply, neither to transactions within states nor to transaction between states because no supreme authority higher than the state exists. As Keohane (1985) notes, world government does not exist, uncertainty is pervasive, and as a result, transaction costs are high in sovereign transactions. In such settings, game theorists call them 'non-cooperative' (Barrett 2003), credible commitment to future behaviour becomes essential if one wants to encourage other players to cooperate. Given that the value of an artificial commodity such as emission rights can be nullified by the stroke of a politician's pen, the quality of institutions and the checks and balances within and between states play a large role for the efficiency of climate policy.

Before introducing the conceptual framework of the thesis in more detail, the next section presents the motivation for this research project and its main questions and methods.

Research frame

Motivation

The inspiration to address a research question often emerges from the *zeitgeist*, the broader events and ideas the researcher is exposed to. In the years 2008/2009, when this doctoral project started to gain shape, the academic debate on climate policy was dominated by a paradigm that emphasised the need for a global cap-and-trade system for greenhouse gas emission rights. The essence of the 'carbon market paradigm' is this: the best way to mitigate climate change is to define a limited amount of usage rights in the atmosphere as a sink for manmade greenhouse gases, allocate these rights, and allow their owners to trade them freely. The economic rationale behind a carbon market rests on the proposition that trade in emission rights would mitigate the pollution problem at least cost because rights could flow to their highest value use until marginal abatement costs converge across all geographical regions and economic sectors (Dales 1968). Many economists, first in the USA (Tietenberg 1980), have hence advised their governments to negotiate a set of emission reduction targets and timetables that would form the basis of a global carbon market.

One implementation barrier for the global carbon market, however, is that the explicit definition and allocation of usage rights for the atmospheric carbon sink implies that a large part of the global oil, gas and coal reserves must remain unused because any emissions limit related to a meaningful climate stabilisation target renders emission rights scarcer than fossil fuels (Meinshausen et al. 2010). Governments hence need to carry out an international transaction that transforms the scarcity rent enjoyed by the owners of fossil resources into a 'climate rent' enjoyed by the owners of emission rights (Edenhofer et al. 2011). In my view, the dominance of the global carbon market paradigm in the economic discourse was one

main reason for the failure of the Copenhagen Summit because the transaction costs of agreeing on a global contract that defines such enforceable emission limits outweigh its benefits from a policymaker's perspective.

There seems little risk of an overstatement if one claimed that atmospheric stabilisation probably is the most challenging transaction ever attempted. Transaction costs seem pervasive in climate policy but, as the Intergovernmental Panel on Climate Change (IPCC 2001: 52) concluded in its Third Assessment Report, "[u]nfortunately, such costs are not fully covered in conventional cost analyses… Considerable work needs to be done to quantify the institutional and other costs of programmes, so that the reported figures are a better representation of the true costs…". This knowledge gap largely persists to this day. IPCC Working Group III makes zero mentioning of the term "regulatory uncertainty" in its Fourth Assessment Report (IPCC 2007), and the same applies for its most recent report (IPCC 2011) which analyses renewable energy technologies and support policies in 1088 pages.

Ironically, ignorance toward transaction costs stays both because and in spite of the ideas of Ronald Coase who introduced transaction costs in modern economic theory (ibid 1937) and established its link to property rights and to pollution externalities (ibid 1960). Coase (1992: 716) laments that *"the world of zero transaction costs has often been described as a Coasian world. Nothing could be further from the truth. It is the world of modern economic theory, one which I was hoping to persuade economists to leave."* If transaction costs exist and if they vary from institution to institution, taking them into account in economic analysis seems worthwhile because it might lead to better policy recommendations.

Insights from New Institutional Economics (NIE) provide some understanding of how political and economic exchange works if institutions and information are not complete and if transaction costs are not equal to zero. It is hence somewhat ironic that two months prior to the political failure of the carbon market paradigm at the Copenhagen summit in December 2009, two NIE theorists received the most prestigious economic science award in Stockholm. Elinor Ostrom and Oliver Williamson shared the Nobel Memorial Prize for their contributions on the role of institutions in economic governance, and Ostrom's focus on common pool resources and Williamson's theory of transaction costs greatly influenced the perspective presented here.

Questions and methods

The purpose of science is often characterised as answering 'why' questions through the provision of causal explanation. Why does the Earth move around the Sun? Why do carbon dioxide emissions warm the Earth's surface? Natural scientists answer why questions by uncovering natural laws such as Newtonian physics and the greenhouse effect, and based on these laws they predict future events with varying degrees of confidence. Social scientists, however, tend to be cautious with predictions because they do not deal with *natural objects* such as planets and molecules but instead they deal with *social subjects*. There is no natural

law like regularity on which economists could base explanation and prediction of human behaviour, primarily because humans possess a free will (Hausman, 2007). A related reason is that social science claims can be both self-fulfilling and self-defeating because they influence individuals' expectations, beliefs, and ultimately behaviour.

The assumption of free will, however, does not imply that human action is completely unpredictable. Otherwise it would be fatal to cross a street just because the traffic light showed green for pedestrians. Even if human behaviour is not deterministic, it shows regular patterns. These patterns often are the result of institutions, informal and formal rules that guide human behaviour (North, 1990). From a purely instrumental perspective, people develop institutions to constrain their individual freedom, ultimately, to reduce social uncertainty and to enhance their individual freedom as a member of a group. Each institutional environment is unique and often the result of social conflict and learning over long-periods of time. An important function of social science hence lies in providing understanding of human behaviour through institutional analysis and interpretation. "The type of social science in which we are interested", argues Max Weber (cited in Hausman 2007: 60) "is an *empirical science* of concrete *reality (Wirklichkeitswissenschaft).* Our aim is the understanding of the characteristic uniqueness of the reality in which we move."

This thesis attempts to make a contribution to institutional understanding by addressing the following three main research questions:

1. **How can a state address regulatory uncertainty in national carbon pricing when there is no external enforcement mechanism?**
2. **How can a state address regulatory uncertainty in international climate finance when there is no external enforcement mechanism?**
3. **What are the limits of a contractual view on climate policy?**

Table 2: Main research questions

The last section of the Introduction ("A heuristic framework for climate contracting") explains in more detail the rationale of these questions and links them to transaction cost theory. For now it suffices to briefly highlight their complementary logic. The first question addresses the problem of credible commitment in *national regulation* with an emphasis on the *temporal* dimension. The second question addresses the problem of credible commitment in *international procurement* with an emphasis on the *spatial* dimension. The third question addresses the limits of the perspective used to answer the other two questions.

Institutional understanding can be gained through both qualitative and quantitative analysis.

The main methods used to explore the problem of credible commitment in climate policy are qualitative and include i) literature review, ii) direct observation, and iii) expert interviews and discussions with policymakers. Time and place of direct observations focused on a five months long traineeship in the climate finance unit of the European Commission. The traineeship allowed me to gain a more detailed understanding of how policymaking organisations determine the behaviour of political and economic agents and how their behaviour in turn determines the institutional environment. Empirical evidence collected through participatory observation tends to be subjective but can nevertheless inform an ad-hoc judgment on the usefulness of different theories of institutions. Based on this experience, I selected New Institutional Economics (NIE) as the theoretical home for my analysis and applied in particular three branches therein to the problem of credible commitment: transaction costs theory, principal-agent theory, and the theory of property rights.

Some words on the limits of a qualitative approach seem warranted before coming to the key concepts of NIE in the next section. Many good things can be said in favour of quantitative methods including formal models that compel through their analytical rigour and manipulability. Nevertheless, a mainly qualitative approach was chosen here not because it was thought superior to any other but because it best fits the author's research interest and because it allows for capturing a broader range of relevant issues while also paying attention to institutional detail that often goes lost in the process of mathematical abstraction. Rather than seeing both approaches in competition, they should be seen complementary. Chapter 3 and Chapter 4 might provide an example of methodologically complementary research because the former conceptualises different commitment devices and their trade-offs while the latter adds detail by selecting one device and analyses its effects in a game-theoretic formal model.

A new institutional view on climate policy

New institutional thinkers form no homogenous academic group but share the common goal to advance our understanding of political and economic exchange by explicitly focusing on the role of institutions (Williamson 2000). Their goal is not to develop an alternative view that could replace neoclassical analysis but rather to offer a complementary view that could cast light on areas that would otherwise remain shady. To better understand how the new institutional perspective differs from the more conventional contributions to the economics of climate change, key concepts are introduced in juxtaposition to neoclassical theory.

Institutions and incentives

Neoclassical economists often deal with production costs by focusing on supply and demand, on allocative choices over production factors, technologies, and prices. One valuable tool in neoclassical perspectives on climate policy are social planner models that

calculate the cost of atmospheric stabilisation based on a detailed representation of the energy system including its technology and resource endowments (Edenhofer et al. 2009). The social planner (an assumed omniscient, omnipotent, and benevolent dictator) thereby optimises a set of production functions that directly transforms decisions into actions and inputs into outputs. Akin to Robinson Crusoe on his seemingly deserted island, the social planner is the sole entity that makes choices over supply and demand in the 'economy'. Williamson (2005) calls the neoclassical perspective the 'lens of choice' and contrasts it with the new institutional 'lens of contract'. He argues that while the neoclassical view of organisations (the firm, the state) as production functions is well suited to capture production costs, it does so at the expense of losing sight of transaction costs.

What are transaction costs? Consider Robinson Crusoe whose economy changes in a fundamental way when Friday comes along (Steven Cheung cited in Allen 2000): the division of labour (and land, and capital, and information) now gives rise to costs of coordination and cooperation, brief transaction costs. From Adam Smith we have learnt that the productivity of the economic system depends on the division of labour. Coase (1998: 73) highlighted that such “specialization is only possible if there is exchange – and the lower the costs of exchange (transaction costs if you will), the more specialization there will be and the greater the productivity of the system.” The same holds true for the kind of specialisation that focuses on the reduction of harmful emissions such as greenhouse gases.

Transaction costs are to the social world what friction is to the physical world and institutions are 'social technologies' to address friction. If a group of people adheres to the same set of institutions (formal and informal rules that guide human behaviour), an organisation emerges (North, 1990). The state is an organisation that owns the right to use ultimate coercion within its borders. Some organisations nest in others so that the rules of the higher-tier organisation (the state) form the institutional background for the lower-tier organisation (the firm). Climate policy deals with a global collective action problem and as such involves the largest conceivable number of individuals and nested organisational relationships. Looking through the ‘lens of contract’ can hence be useful if one wants to understand how atmospheric stabilisation can be organised rather than produced.

	Neoclassical view	**New institutional view**
	lens of choice	*lens of contract*
Focus	production cost technology	transaction cost institution
Cognition mode	hyper rationality	bounded rationality
Property rights	complete	incomplete

Table 3: Key differences between neoclassical and new institutional economics.

A second important strand of research in the economics of climate change uses game-theoretic models to identify optimal strategies that players should follow (Barrett 2003). Game theorists accept the existence of multiple actors with conflicting interests and asymmetric information and use formal models to calculate strategic moves of agents within a given incentive structure. Questions such as how to bind agents to agreements across space and time in a non-cooperative setting are posed and usually the following answer is provided: agents can be bound when the gains from living up to an agreement exceed the gains from defecting (Schelling 1960). Although game theorists have developed some highly ingenious models of such self-enforcing incentive structures, they do however not answer the key question of how to realise these structures (North 1990). Though incentives are a function of institutions, game-theoretic models often remain safely remote from institutional detail. Moreover, by relying on the rational expectations hypothesis, game theorists usually assume that agents know the exact probability distribution of future states of the world including the response strategies of other actors. Knight (1921) introduced the important distinction between risk on the one hand, where alternatives and their probabilities are known, and error and true uncertainty on the other. For new institutional economists, the functional value of institutions precisely lies in their capacity to manage transactions under 'Knightian' uncertainty, e.g. by resolving conflict if property rights remained incomplete because a contract did not include provisions for unforeseen contingencies.

The possibility of having incomplete contracts is only possible if one abandons one fundamental assumption in neoclassical economics: the rational expectations hypothesis. The presence of true uncertainty in decision-making becomes acknowledged by supplanting the rational expectations hypothesis with a rationality of individuals that is limited by their cognitive capacities, the finite amount of time they have to collect information and make decisions. This has important consequences for economics because, as Herbert Simon (1985: 303) notes, "Nothing is more fundamental in setting our research agenda and informing our research methods than our view of the nature of the human beings whose behaviour we are studying". Simon's view of cognition is that human behaviour is "intendedly rational but only limited so" (1957: Xxiv). One important consequence of bounded rationality is that information and institutions, including property rights, remain incomplete because agents cannot foresee and contract all future contingencies. The incompleteness of information and institutions, in turn, are key drivers of transaction costs.

Transaction costs

The organising principle of the contractual view propagated by Coase, North, Williamson and others is that of transaction costs (for a review in environmental economics see Krutilla and Krause 2010). Despite the central importance of the term, the literature lacks a commonly shared definition. Even Coase, who introduced the concept, never went beyond the provision of examples: In order to carry out a transaction, Coase (1960: 423) observes

that *"it is necessary to discover who it is that one wishes to deal with, to inform people that one wishes to deal and on what terms, to conduct negotiations leading up to a bargain, to draw up the contract, to undertake the inspection needed to make sure that the terms of the contract are being observed, and so on."* He also points to the problem of enforcement. Allen (2000) reviews the literature and identifies two major strands: the *neoclassical tradition* defines transaction costs as the costs resulting from the transfer of property rights in the market place. That means that institutional costs within organisations (e.g. principal-agent problems) do not count as transaction costs. Transaction costs that are internal to organisations, however, do play an important role (Alchian and Demsetz 1972) and can be captured by the definition of the second tradition identified by Allen (2000): the *property rights tradition*, which also is the one underpinning this thesis (see Table 1): transaction costs are the costs of establishing and maintaining property rights.

Furubotn and Richter (2010) relate transaction costs to six basic activities that occur before, during, and after contract formation (Figure 1). Coase (1937), for instance, focuses on pre-contractual activities (1; 2) and contract formation (3) while Williamson (1985) highlights the importance of post-contractual uncertainties (4; 5; 6). The process steps displayed below are all interrelated and so are the costs. For instance, if contracts are not enforceable, agents will spend more resources on search and inspection to ensure a higher degree of interest alignment with their counterparty (Williamson 1985). They might also decide to form a contract whose value is less dependent on the successful completion of the transaction. For instance, if a firm cannot trust the regulator's promise to maintain a carbon price high enough to recuperate the sunk cost of developing a low-carbon technology, it will invest in less costly and less carbon-efficient technologies (see Chapter 3). The resulting technological inefficiency in production is a *realised transaction cost* that accrues instead of other, *avoided transaction costs* that agents expected to be higher. Moreover, the definition also captures the costs of maintaining property rights even if no transfer is taking place. Consider for instance the failed negotiation of a cap-and-trade bill in the USA during 2009. Firms in the oil, coal and utility sectors spent US$500 million to lobby against this climate policy in order to protect their property rights (New York Times 2010). The formation of a new institutional regime failed because interest group successfully maintained their property rights.

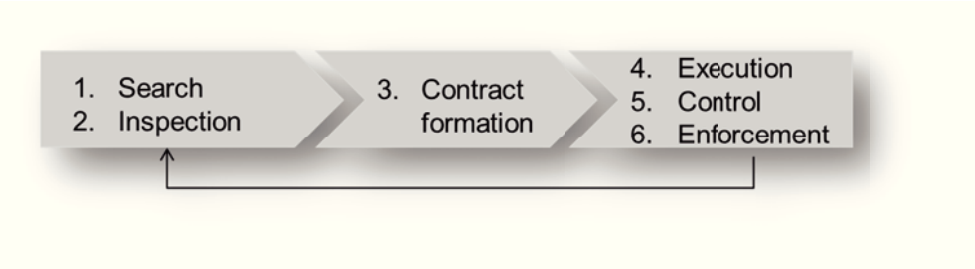

Figure 1: Basic contracting sequence.

A high level of conflict is not the only cost driver in political contracting. Political transaction costs tend to be high because political agents, in contrast to private agents, pursue multiple

and often difficult to define objectives (Tirole, 1994; Dixit 2002). Owners of private firms, for instance, set their managerial agents to have the goal of 'profit maximisation'. Some measurable variables such as stock prices or earnings are closely related to this goal and can be used to structure agents' incentives. The objective function of political agents, however is multidimensional not at last because the objectives of political constituents are multidimensional. Hence, other objectives such as equality, security, etc. must also be taken into account that are difficult to define and measure, and that may be weighted differently by different people or by the same people but at different moments in time. The opacity and multiplicity of goals increase the costs of search and inspection, also because positive uncertainty, the many ways in which the state of the world can change, provides abundant excuses to deviate from past agreements.

	Transaction cost economics *Williamson (1985)*	**Transaction cost politics** *Dixit (1996)*
Process:	economic exchange 'play of the game' private ordering	political exchange 'rules of the game' public ordering
Actors:	consumer/ producer	citizen/ politician
Goods:	mostly private	mostly public
Objectives:	single objective easy to measure	multiple objectives difficult to measure

Table 4: Principle features of transaction cost economics and transaction cost politics

A heuristic framework for climate contracting

After having introduced the basic concepts of New Institutional Economics we can now introduce a heuristic framework for climate contracting and link it with the main research questions presented in Table 2 above. From a contractual perspective, climate policy acts can be clustered along the two principle types of intervention: regulation and procurement (Table 5). Laffont and Tirole (1993, p. 8) refer to "procurement when the firm supplies a good to the government and to regulation when it supplies a good to consumers on behalf of government". Procurement offers money to those who deliver an output the government wishes to acquire. Regulation, on the other hand, embodies a coercive element because it forces agents to act in a certain way. A common example for carbon regulation is a command-and-control type emissions standard for industrial facilities. But carbon pricing too falls under regulation because agents are coerced to pay a price per unit of emissions. An important difference between both policy types is hence whether incentives are coercive. Akin to the master who steers his mule with sticks and carrots, policy-makers can use regulation and procurement to encourage agents to alter their behaviour.

National regulation and international procurement gain relevance as complementary policy types as soon as one leaves the global carbon market paradigm to engage with non-cooperative settings of climate policy. Assume the government of a high income country wants to encourage emissions abatement within but also beyond its borders. It would want to use carbon pricing within its borders because pricing the emissions externality serves to efficiently remedy the market failure produced by it (Chapters 2 to 4). (Note that 'efficiency' here stands for a Pareto-optimal general equilibrium in a competitive market framework. In this framework, transaction costs are assumed to be zero). It also wants to abate emissions in other countries, mainly low-income countries, because they are assumed to offer abatement opportunities at lower marginal costs (Chapter 5). Low income countries usually prefer spending their own limited resources on actions other than climate change mitigation such as immediate poverty alleviation. International cooperation on climate change mitigation would hence need to rely on procurement, a lateral exchange, rather than regulation because a sovereign state cannot be coerced to impose a price on its emissions (Figure 2). Donor states could compensate recipient states for the economic costs of carbon pricing but this action too is a form of procurement because it involves the voluntary consent of the recipient state. Such 'procurement of regulation' offers some advantages over project-based interventions, and the UNFCCC process is trying to introduce this policy type in the emerging climate finance framework.

	Carbon pricing	**Climate finance**
Intervention type	regulation coercion	procurement choice
Target group and incentive	polluters pricing public bad	innovators subsidising public good
Paradigm	carbon market (environmental policy)	green economy (industrial policy)

Table 5: Typology of climate contracting

Academic interest in the distinction between carbon pricing and climate finance usually focuses on the question of how to best address the market failure related to the emissions externality. The argument then is that since carbon pricing does not provide sufficient incentives for innovation because of technological spill-over effects, targeted technology subsidies are needed to achieve an optimal outcome in a 'second-best' setting (e.g. Kalkuhl 2012). This type of analysis, although highly relevant for climate policy, is not the focus here. In the following chapters, climate policy is analysed from a strictly institutional perspective: how can a state deal with regulatory uncertainty arising from the infeasibility of third-party enforcement and what trade-offs does this action imply? Given that the answer to this question depends on the type of institutions available to address uncertainty (national or

international), the distinction between carbon pricing and climate finance seems crucial for policy evaluation and policy choice.

The remainder of the thesis proceeds as follows: Chapter 2 reviews design elements of emissions trading systems and identifies regulatory uncertainty as one major obstacle for efficient carbon markets. Chapter 3 explicates the sources of regulatory uncertainty in carbon pricing, compares different commitment devices, and qualitatively evaluates the trade-off between valuable commitment and valuable flexibility. Chapter 4 assesses this trade-off in a game-theoretic model and finds that a state-contingent adjustment rule is the optimal way to provide commitment under uncertainty. Chapter 5 discusses the infeasibility of commitment in international climate finance and its effects on transaction costs. Finally, the Conclusions distil the main lessons learnt both in terms of content and process of the research project.

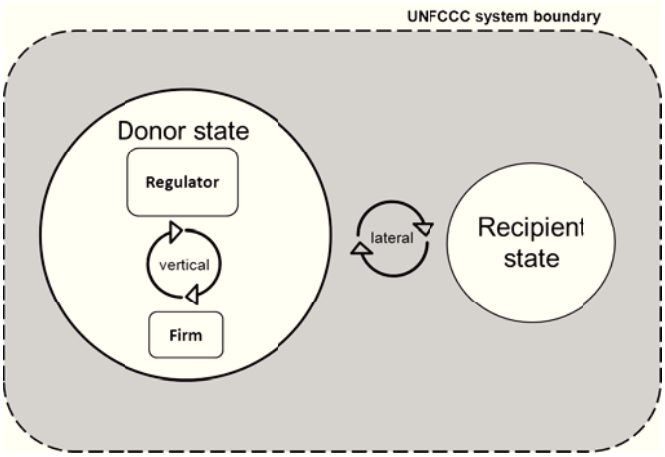

Figure 2: A heuristic framework for climate contracting

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2 Domestic Emission Trading Systems

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Introduction

The EU Emissions Trading Scheme (EU ETS) is the centrepiece in Europe's climate policy architecture and the largest cap-and-trade system in the world. After having failed to introduce a union-wide carbon tax during the 1990s, the European Commission presented a 'Green Paper' in 2000 that proposed the use of emissions trading. Launched in January 2005, the EU ETS established a uniform carbon price for specific heavy industry activities in all EU member states. It covers CO_2 emissions from over 10,000 installations, including power and heat generators, oil refineries, and factories for ferrous metals, cement, lime, glass and ceramic materials, and pulp and paper. Together, the covered sources account for roughly 40% of total EU greenhouse gas emissions.

This background paper reviews the characteristics and experience of domestic emissions trading as an instrument of climate policy. The rationale of emissions trading and its general principles are briefly summarized in section 1. Section 2 highlights the basic design elements of cap-and trade, and section3 reviews the main lessons from the EU ETS. Finally, section 4 summarizes the conclusions.

Rationale of emissions trading

At the very heart of emissions trading lies the notion that if "factors of production are thought of as rights, it becomes easier to understand that the right to do something which has a harmful effect [...] is also a factor of production" (Coase 1960, 44). The cost of exercising such a pollution right should be equivalent to the loss that is suffered elsewhere in consequence of this action. Making these rights explicit and transferable enables the market to value and trade them. As a result, emission rights can flow to their highest value use and reductions can occur wherever they are cheapest. Figure 1 below illustrates this effect. Imagine polluter A with a marginal abatement cost (MAC) curve A, and polluter B with a relatively steeper MAC curve B. Given a certain emission limit (left dotted line) and without emissions trading, both polluters would have to reduce emissions until they comply with their individual abatement obligation. Polluter A would face relatively low cost, polluter B relatively high cost for a given quantity. With emissions trading, A will want to increase and B decrease abatement until marginal abatement costs converge at price P. The efficiency gain of A is illustrated by area a which comprises the benefit from increasing abatement and selling freed up allowances to B. The efficiency gain of B is illustrated by area b which

represents the amount of saved abatement cost net of the money paid to A.

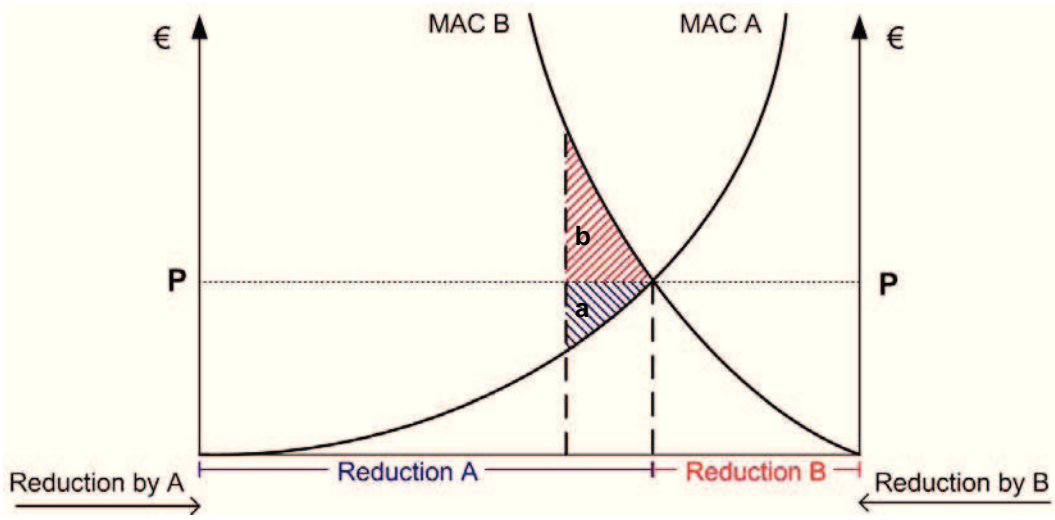

Figure 1: Efficiency enhancing effect of emissions trading

After the groundbreaking work of Coase in the 1960s, scholars quickly began to point out the instrument's usefulness for air pollution control. Tradable emission permits have been successfully used in the US since 1995 to tackle the problem of acid rain by reducing sulphur dioxide and nitrous oxide emissions.

Two broader categories of domestic emissions trading systems (ETS) can be differentiated: systems which limit emissions at relative or at absolute levels (Reinaud and Philibert 2007).[2] Relative targets can either apply to country or sector/firm level. It is also possible to combine relative targets for some sectors with an absolute target at country level. Relative targets can be based on emission intensity per unit of output or other indexes and have been proposed as a means to address cost concerns as they better encapsulate the notion of decoupling economic growth from emissions (Marschinski and Lecocq 2006). Ellerman and Wing (2003) contend that intensity targets can reduce the uncertainties associated with abatement costs under uncertain economic conditions. Pizer (2005) finds that intensity targets may be more appropriate if the short-term objective is to slow, rather than halt, emissions growth.

Systems based on absolute targets cap emissions from covered entities and allocate emission allowances to participants which can then trade them among each other. Under

[2] The relative merits and drawbacks of both types is subject of an ongoing academic debate (e.g. Quirion 2005; Sue Wing et al. 2006; Newell and Pizer 2006).

cap-and-trade, compliance is established by comparing total actual emissions with the amount of allowances a particular participant holds. Dudek and Golub (2003) argue that absolute caps have more certain environmental results and lower transaction costs for emissions trading, thereby creating stronger incentives for technological change. IPCC (2007a) conclude that absolute targets are more effective than intensity targets if the aim is to meet certain emission reductions, but they may be less effective at addressing costs when the economic outlook is uncertain. The majority of currently existing, announced, and proposed schemes apply cap-and-trade (see BP3) and the remainder of this document shall therefore focus on this type of emissions trading.

Elementary design features of cap-and-trade

In theory, there exists a wide range of different cap-and-trade system designs. Table in the Appendix summarizes the major characteristics of the EU ETS, the Regional Greenhouse Gas Initiative (RGGI), and proposals for systems in California, Australia, and New Zealand. While they differ widely in their specific rules, they all build on a limited number of design elements which enable policymakers to strike a balance between a programme's environmental effectiveness, cost effectiveness, distributional impact, and institutional feasibility.

Cap and coverage

The coverage identifies the scope of an ETS in terms of emission sources and greenhouse gases. Emissions sources are usually covered at sector level, where minimum thresholds are defined to exclude very small sources. This can avoid that transaction costs of including additional sources exceed the environmental benefits.[3] The cap defines the maximum level of greenhouse gases these sources may emit during a certain period of time. Several studies have found that full coverage of emissions sources within an ETS is superior to partial coverage because it ensures that marginal costs are equalized across the entire economy. Böhringer and Löschel (2005) find that in the EU significant cost-savings would result from economy-wide coverage compared to exclusion of certain sectors. Given the substantial abatement options in different economic sectors such as buildings and transportation (McKinsey 2007), it is important to make these options accessible for the market by covering all relevant sectors by the cap. This can be done up-stream in order to minimise transaction cost. The EU ETS, however, excludes buildings and transport from coverage, leaving their

[3] The EU ETS covers more than 10.000 different installations, 7% of which account for 60% of total emissions. In contrast, the 1.400 smallest sources account for less than 0.14% of emissions (EC 2008). Reducing the number of covered sources can cut a programme’s cost without significantly affecting its environmental effectiveness, but only if there is no leakage from larger to smaller sources. Alternatively, upstream coverage automatically includes all sources within a sector.

abatement potential inaccessible for the trading sector.

Complementary measures such as insulation and fuel efficiency standards should be employed in order to exploit the abatement potential of non-covered sectors. In fact, the presence of negative abatement costs indicates that market failures exist which impede the exploitation of options that would be beneficial even in absence of climate policy. However, it needs to be taken into account that as long as such activities are not subject to a binding constraint on overall emissions e.g. through a cap, rebound effects will occur. As higher efficiency reduces the costs of an activity (e.g. transport, heating), this will lead to an expansion of the activity level. Thus, emission reductions may not be as large as suggested by initial assessments of reduction potentials from efficiency measures that do not take into account rebound effects. Moreover, even if a certain sector previously excluded becomes covered, complementary policies continue to be necessary in order to address the pre-existing market failures indicated by negative abatement costs. Both, an absolute cap on emissions and complementary instruments are required to reduce emissions in a cost efficient manner.

Broad coverage can also widen the potential for carbon market liquidity and efficiency (Baron and Bygrave 2002). Introducing more sources and sectors to a market can also reduce the impact of economic shocks in any one sector on the trading system as a whole. However, this comes at the expense of partly transferring shocks into other sectors via the permit market. In addition, the larger and more liquid a market, the harder it is for large players to affect the overall price level. However, sectors for which emissions cannot be quantified and monitored with certainty (e.g. N_2O and CH_4 emissions from agriculture) should be managed with alternative measures and remain excluded from the cap until sound methodologies of measurement and monitoring have been developed. Otherwise, the inclusion of unverifiable emissions could undermine the cap's environmental integrity (Herold 2008).

Another key aspect in designing ETS is identifying the appropriate incidence of regulation (BP1). The point of obligation defines the liable party for surrendering emissions permits. In an upstream design, the point of obligation can for example lie at the level of importers and producers of fossil energy.[4] Small energy-related sources, e.g. in the transport sector, can be effectively covered by moving the point of obligation upstream. Importers and producers of fossil resources would then pass on the price signal to resource users, who will adapt their economic activities according to this change of input prices. In a downstream design the point of obligation can be the emitting installation or the final consumer of fossil energy. A

[4] Because the amount of CO_2 emitted from burning a unit of coal, oil or gas is largely invariant to the process in which it is oxidized, emission factors can be calculated easily on the level of fossil primary energy carriers. Indeed, observing coal use and calculating emissions from it rather than observing emissions in the flue stack is the standard procedure for calculating emissions e.g. for large-scale users of coal in the EU ETS, and also in national emissions inventories under the UNFCCC.

hybrid system combines both approaches, where some sectors are included up- and others downstream (Hargrave 1998).

While CO_2 related to the combustion of fossil fuels accounts for the bulk of man-made emissions, several other sources and compounds also contribute significantly to global warming. Currently, CO_2 release due to deforestation, mostly in tropical countries, accounts for almost 20% of the emissions (IPCC 2007b). In terms of CO_2 equivalents, emissions of methane and nitrous oxide from agriculture make up 14% of the global total. Agricultural emissions have risen continuously and are particularly difficult to reduce. Other significant sources are nitrous oxide and fluorinated gases from industrial processes. Many of these emissions can be reduced at low costs. A major concern often voiced is that including low-cost abatement opportunities and offset credits will, in the short term, crowd out other mitigation activities and thus delay the structural energy sector transformation that is necessary for the long-term achievability of ambitious climate stabilization targets. This problem is mitigated by setting appropriately tight short and medium term reduction targets in order to ensure sufficient incentives for low-carbon energy investments and intertemporal cost-optimality, while taking advantage of low-cost emission reduction opportunities.

Generally, governments need to be as clear as possible about the future development of cap and coverage, as they are the major determinants for emission prices. For making long-term investments with confidence, market participants require predictability. Clear signals of support for stringent future caps from governments will enhance predictability. This requires in particular the definition of a long-term reduction trajectory. After all, greenhouse gases are stock pollutants. Their climate effect depends primarily on the long-term emission budget rather than reduction targets for certain points in time.

Importing offset credits

ETS coverage can also be extended by allowing for the import of offset credits. Emission reductions in sectors or countries not covered by the ETS can be certified and redeemed to offset emissions under the cap. The Clean Development Mechanism, for example, is the largest offset credit programme in the world with a market value of US$ 13 billion in 2007 (World Bank 2008). Allowing the import of offsets will lower compliance costs if the marginal costs of creating credits are lower than the allowance price in the cap-and-trade system. This might be sensible for sectors in which emission levels and reductions are difficult to measure for all sources, such as forestry, agriculture, and waste. Partially covering these sectors in the ETS might lead to intra-sectoral distortions, whereas allowing them to generate project-based credits can provide incentives for mitigation without generating distortions (Garnaut 2008). The planned Australian ETS, for instance, allows for domestic forestry offsets in order to provide incentives for this sector before it becomes eventually covered under the scheme. The European Union is also planning a new domestic offset mechanism from 2013 onwards (EC 2008), and the RGGI system also includes a domestic offset credit system (RGGI 2007).

There are, however, risks connected to the import of credits. First, the excessive reliance on offsets to meet abatement obligations may jeopardize a programmes environmental effectiveness. This concern arises when the additionality of offset credits cannot be fully guaranteed.[5] Offsets are rewards for reductions in emissions measured against an assumed baseline: 'what emissions would have occurred in the absence of the credit mechanism'? Determining a counterfactual baseline can be arbitrary to some extent, resulting in the risk that schemes do not promote genuine abatement. Second, the import of relatively cheap abetment options via offset credits drives down allowances prices under the cap which in turn reduces the financial incentive for investing in domestic emission reductions. This can be a problem if a certain level of domestic abatement and certain incentives for investments are an ETS policy objective. From an environmental point of view, however, it does not matter where GHG emissions are reduced internationally as they equally contribute to global warming. To address these previous concerns an ETS can limit the amount of credits that can be used. The EU, for example, limited the import of Certified Emission Reductions generated under the CDM into the EU ETS to 13,4%. Limiting the import of credits does, however, not address the problem of additionality (except when limiting the import quota to zero), and can only contain the scale of the problem. Additionality concerns are best addressed by applying rigorous additionality procedures, and/or reforming the credit scheme accordingly. Discounting offset credits is another option to address uncertainty over project additionality.

Allowance allocation

After the cap has been set, the ETS operator issues allowances for units of emissions (e.g. metric tonnes CO_2[6]) where the total number of permits equals the cap. This step is a contended issue in virtually every cap-and-trade programme as it critically determines the policy's distributional impact. Allowances can either be sold, usually through auction, or allocated for free. The key question is who receives the scarcity rent created by capping emissions.

In principle, there are two options for free allocation: grandfathering and benchmarking. Grandfathering allowances means that permits are distributed in proportion to past emissions, measured for one or several years. Grandfathering can either be a one-off allocation to existing sources, or be regularly updated with new emissions data. Benchmarking constitutes a method where allowances are distributed on the basis of an average or expected performance benchmark. For instance, it can provide fixed allocation quantities based on expected output. Under free allocation, emitters receive the full value of

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[5] See for example Wara and Victor (2008) or Schneider (2007) who provide a critical analysis of the Clean Development Mechanism's environmental performance.

[6] The RGGI system uses short tons.

allowances for free and pass on the opportunity costs of allowances to consumers wherever possible. The scarcity rent of allowances is thereby appropriated by the private sector, generating windfall profits for emitters and higher output prices for consumers.

There are a number of reasons why free allocation may distort incentives for reducing emissions (Hepburn et al. 2006). First, the expectation that the baseline year upon which allocations are based will be updated may encourage sources to invest in dirty technology or refrain from investing in clean technology in order to increase or maintain emissions levels and thus receive more free allowances in future. One needs to be cautious to avoid this kind of perverse incentive, for example by choosing a baseline year in the past or by combining baselines with benchmarks. Second, free allocation may present a barrier to market entry. If existing polluters receive allowances for free but new entrants are obliged to buy them, free allocation directly disincentivises market entry, reducing competition. At the same time, it may present a barrier to market exit. The requirement that an installation must be kept open in order to receive free allowances may prevent the closure of inefficient plants, freezing emissions at higher levels than otherwise necessary. Third, grandfathering leads to increased lobbying activities because emission allowances, which have a monetary value, are given out for free. Lobbying of powerful producer groups may put governments under considerable pressure; a time consuming and costly procedure.

Auctioning offers several advantages over free-allocation. First, it puts upfront costs on polluters. This will tend to enhance managements' awareness of carbon cost, leading to more efficient decisions. Second, auctioning enables governments to use revenues to address equity issues through reductions in taxes or other distributions to low-income households. Governments can also use auctioning revenues to invest in the development and deployment of cleaner technologies, or provide finance for other countries' efforts for climate change mitigation and adaptation. This is analogue to the 'double dividend' feature of carbon taxes. Goulder et al. (1999) demonstrate that recycling revenues from auctioned allowances can have economy-wide efficiency benefits if they are used to reduce distortionary taxes. Dinan and Rogers (2002) show that free allocation of tradable permits may be regressive because it leads to income transfers towards higher income groups (i.e. shareholders) at the expense of poorer households (i.e. consumers with high income shares of energy expenditure). Third, Tietenberg (2006) contends that auctioning provides stronger incentives for technological innovation. Under grandfathering some sources are buyers and others sellers. Sellers have an incentive to behave strategically and keep prices high by avoiding technological innovation. In auction markets, all emitters are buyers. Hence, all sources benefit from low-carbon technologies via decreased marginal abatement cost and permit prices.

Allocation methods for sources entering or leaving the scheme represent a contentious issue. New entrants and closure provisions define whether new entrants have to either buy/receive additional allowances from a new entrants reserve or be obliged to buy permits on the market (Ahman et al. 2006; Ellerman 2006). Free allocation would be more

favourable to encourage new investments, as the obligation to buy allowances represents an additional barrier to market entry and might impede the renewal of facilities. However, if free allocation to new entrants is based on actual emission intensity, it provides a disincentive to install more efficient technology, contrary to the overall aim of carbon pricing. Grubb and Neuhoff (2006) therefore suggest to base free allocation for new entrants on the basis of technology specific benchmarks.

Overall, auctioning can avoid many of the problems associated with free allocation and offers distinct advantages. But good design is necessary to avoid new inefficiencies. Small frequent auctions may be more effective in limiting the market power of large bidders (Hepburn et al. 2006). They may also encourage learning processes, help players to adjust bids, and promote price stability. In contrast, one large auction at the beginning of each trading period may minimise administrative cost. However, it may also enable large polluters to buy the bulk of permits which can then use them to extract oligopoly rents on the secondary market. The optimal design for auctions in cap-and-trade systems is subject of ongoing research (Neuhoff and Matthes 2008).

Banking and borrowing

Economic theory states that the efficiency gains from emissions trading stem from equalizing marginal abatement costs among spatially distributed sources with different abatement cost curves. In addition, however, there also is a temporal dimension to equalizing marginal abatement costs. Due to economic cycles/shocks, resource price hikes, mild winters, etc. allowance prices can be low in one particular period of time and high in another. However, it would be efficient to reduce emissions when this is cheapest. Theoretically, if the cumulative emission budget remains constant and it does not matter in which period emissions are reduced, this will enhance the efficiency of meeting a pre-defined emissions target. In cap-and-trade systems, temporal flexibility is introduced by banking and borrowing provisions.

Banking means that instead of using an emissions permit at an early date, it is saved for later use because it is anticipated that its value in later periods will be higher than now. As a result, abatement options that are cheaper now than the net present value of a future allowance will be utilized, thus increasing the amount of early abatement relative to the case without banking. Allowance banking can help to equilibrate present value prices across trading periods. Ellerman and Pontero (2005) analyse the use of banking in the US Acid Rain Program. They find that sources banked 30% of permits in phase one (1995-1999), probably due to the expectation of tighter caps in later phases. As a result, emission reductions in phase one were twice as high as needed to meet the cap. Fell et al. (2008) demonstrate that banking reduces price volatility and eliminates about 20% of the cost difference between price and nonbankable quantity instruments. The degree of these reductions, however, depends on the persistence of price shocks. Due to these advantages, banking is a feature found in most ETS designs.

The advantages of borrowing, in contrast, are less unanimous. Borrowing means the ability to buy allowances from a future trading period during an earlier trading period. While in theory, borrowing can significantly enhance economic efficiency of achieving a cumulative cap, concern over the instruments impact on policy consistency exist. As excessive borrowing undermines early abatement, it is likely to put upwards pressure on future compliance costs, unless substantial technological change occurs in the meantime. Regulators, faced with considerable political pressure from polluters who refrained from investing in low-carbon technologies early on, might be pressed to cancel out borrowed quotas by increasing future allocations.[7] Sticking to announced allocation budgets might thus become politically untenable. Assuming that borrowed quotas will not be repaid, the dominant strategy from the point of view of an emitter is to refrain from early abatement, create pollution lock-in, and bet on loosened caps in the future. Excessive borrowing from future compliance periods could therefore undermine long-term policy integrity while also depressing short-term allowance prices and hence financial incentives to invest in low-carbon technologies for all other players. Nonetheless, some proposed emission trading programmes include borrowing as a means of cost containment.[8] Under which conditions borrowing can be in line with a stringent trading system and its environmental effectiveness remains subject to further research.[9]

Price ceiling and floor

As noted earlier, under uncertainty and in the near-term carbon taxes tend to be more economically efficient than emissions trading (BP1; Newell and Pizer 2003). Yet, the introduction of carbon taxes has proven to be politically difficult, resulting in a greater emphasis on emissions trading. In order to combine the economic efficiency benefits of carbon taxes with the political feasibility advantages of emissions trading, some scholars have investigated how quantity controls can be reconciled to efficient price policies via the

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[7] Garnaut (2008) argues that good governance and stringent law enforcement can avoid this problem. However, the assumption that governance is good and law enforcement is stringent at all times and everywhere can be questioned. After all, if the political agenda of a legislating body is changed following general elections, former decisions on caps etc. may become challenged and eventually altered.

[8] For example, the US "Bill to Reduce the Economic Impact of Climate Legislation" proposes the establishment of a 'Carbon Market Efficiency Board', which would intervene in a future US carbon market when allowance prices exceed a certain threshold. The first measure is to expand companies' ability to borrow permits. The second measure, to be used if high prices are not relieved by the first measure, is to add permits to the market. This temporary increase would be compensated for by reducing available allowances in a later year.

[9] A special case of borrowing represents intra-period borrowing. This is the case in the EU ETS, where facilities receive allocations for two compliance years prior to the first actual compliance date. That is, until the very last compliance year in a trading period, there are always two allocation tranches in the market at the date of compliance. Intra-period borrowing does not dilute environmental effectiveness.

application of price bounds (Roberts and Spence 1976; Newell et al. 2005).

A price ceiling, also called 'price cap' or 'safety valve', can help to limit cost uncertainty by defining a fixed price at which additional allowances are made available in excess of the cap (Pizer 2002; McKibbon and Wilcoxen 2002; Jacoby and Ellerman 2004). A price floor, in contrast, defines a minimum charge on emissions. Price floors stabilize expectations for developers of low-carbon technologies as they are assured that abatement technologies below the price floor will be marketable. Most ETS designs do not include a price floor. One exception is the Regional Greenhouse Gas Initiative which plans to define a minimum 'reserve price' for allowance auctions. Although this establishes a minimum price for allowances during auctions, it does not guarantee a minimum price during trading periods.

The underlying reasoning of price ceilings is that the atmospheric stock of emissions over the long-term needs not necessarily be affected by a short-term deviation from the reduction path. There may therefore be less concern about short-term increases in CO_2 as long as the overall trajectory of CO_2 emissions is downward over an extended period (Newell and Pizer 2004). Price ceilings can cap expected cost and hereby reduce economic uncertainty. However, the uncertainty would only be shifted from the cost side to the benefit side of reducing emissions. Philibert (2008) estimates that implementing price ceilings and floors in the global climate architecture can reduce mitigation cost by two thirds (from US$ 10,671 billion to US$ 3,456 billion for the 10.5 Gt CO_2 scenario) without greatly increasing global warming (from 2.44°C median increase to 2.49°C by 2050).

Price ceilings, however, can put a cap's long-term environmental effectiveness at risk, especially where they are combined with banking. Suppose market participants expect the emissions cap to be tightened in the near future (e.g. due to new information on the severity of climate change). As a consequence, they also expect a higher price ceiling under the new cap. Market participants would want to buy as many allowances as possible at the current, lower trigger price in order to bank them for later use. An unrestricted safety valve mechanism could thus put much stress on the stringency of long term emission reduction targets (Stern 2007). In addition, price ceilings generate additional administrative complexity, especially in regard to linking different trading systems. The lowest price ceiling among linked trading systems would set the international price ceiling (Flachsland et al. 2008). In order to safeguard the stringency of long-term caps, Murray et al. (2008) propose to limit the quantity of additional allowances available in the safety valve. This "allowance reserve" would stipulate both a ceiling price at which cost relief is provided and a maximum number of allowances available to provide this relief.

Monitoring and compliance

The provision of robust information is a necessary condition for ETS price stability (Stranland et al. 2002). Stringent monitoring, reporting, and verification (MRV) procedures are required to reveal the basis of market supply and demand in a reliable manner, excluding later data

adjustment. The price crash in the first trading period of the EU ETS resulted from the fact that prior to the implementation of the system no reliable emissions data were available. MRV rules ensure that a tonne of carbon emitted by one source is equal to a tonne of carbon reduced by another source. Hence, they are essential for securing the environmental credibility and the financial fungibility of emission permits. The installation of stringent MRV standards may pose a challenge, in particular for countries with weak legal traditions and institutions.[10] Tietenberg (2006) states that emissions trading systems introduce an incentive for cheating regarding the provision of emissions data. Under grandfathering, sources have an incentive to register more historic emissions than actually occurred. Depending on method of allocation, non-registered emissions do not need to be paid for (auctioning) or can be sold (free allocation). For ensuring compliance, excess emission penalties should be set at levels substantially higher than the prevailing allowance price (Swift 2001). An additional incentive for compliance is provided by public access to data because third parties such as traders or NGOs can screen the available information for inconsistencies (Kruger et al. 2000).

Avoiding carbon leakage

In an ideal world, global emissions trading would establish a uniform carbon price for all countries and all sectors (see BP3). But in reality, carbon pricing is only applied partially and unevenly, so that firms facing a cost on carbon might compete with firms who do not. Asymmetric carbon pricing gives rise to concerns over carbon leakage which occurs when domestic production is reduced as a result of carbon costs but (at least some of) the reduced domestic production gives rise to additional production and emissions elsewhere. Trade-exposed energy intensive industries might emigrate to non carbon jurisdictions and/or carbon-constraint sectors might lose shares in the international market. Both outcomes reduce the environmental effectiveness of cap-and-trade. Concerns exist that both effects will also negatively impact competitiveness and employment of carbon-constrained sectors without necessarily benefiting the global environment.[11]

For assessing the risk of carbon leakage one needs to distinguish between direct and indirect price effects generated by emissions trading (Grubb and Neuhoff 2006). Direct costs are caused by emissions originating from the production process itself (which include energy

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[10] Several authors have concluded that tradable permit programmes may be less appropriate for developing countries due to their lack of appropriate market or enforcement institutions. (Blackman and Harrington 2000; Bell and Russell 2002; Victor 2007). For China, Wang et al. (2004) suggest that a strengthened monitoring and enforcement capacity would be required to implement emissions trading.

[11] Reinaud (2008) correctly points out that most discussions of competitiveness effects neglect industries that benefit from climate policy. This is fallacious as climate policy potentially enhances research, development and deployment of lower-emitting technologies and also offers positive competitiveness and employment effects.

and process emissions). Indirect costs are caused by, for example, higher electricity prices: electricity generators pass on opportunity costs of allowances to firms which in turn will result in higher prices for consumption goods. The same indirect cost effect may apply to other intermediate inputs to production which may become more expensive due to pass-through of CO_2 related costs. The German government (UBA 2008) assessed both effects for sectors that may potentially be exposed to distortions in competitiveness. The analysis is based on the concept of value at stake which is defined as the sum of potential direct and indirect costs in relation to the gross value added (GVA) of a given industrial sector. The sectors with relevant value at stake contribute little more than 2% to overall GDP. In other words, most economic sectors are not at risk of carbon leakage.

Grubb and Neuhoff (2006) argue that for most industries, the net value at stake due to adverse competitiveness impacts are lower than 1.5% of sector value-added, and that for EU industries that are affected the most (cement, and iron and steel) import penetration from outside the EU is rather low. This is in line with the findings of the World Bank (2007) which concludes that industrial competitiveness is not seriously impaired by domestic emissions reductions and that the remaining adverse effects can be offset by well designed policy packages. Further, Reinaud (2008) finds limited risk for carbon leakage. Production factors other than carbon costs also influence investment and production decisions: cost and qualification of employees, exchange rates, infrastructure, existence of technology clusters, etc.. With regard to most industrial sectors, carbon cost influence investment decisions only marginally.

For the limited number of sectors which are prone to carbon leakage, one countermeasure is free allocation of emission allowances. However, for those sectors for which the potential value at stake depends mostly on the increase of electricity prices (indirect CO_2 costs), a change in the allocation method would not prevent a potential production cost increase (UBA 2008). For those sectors with high direct CO_2 costs it should be noted that the maximum value at stake is based on the assumption of full auctioning of emissions allowances. Direct costs could be lower if part or all of the allowances were allocated for free, depending on whether, and to what extent, the concept of opportunity costs is applied. Without a functioning international carbon market, partial or totally free allocation for a limited number of industries prone to carbon leakage may be necessary to maintain a level playing field among international competitors.

Another measure which features in the discussion surrounding carbon leakage are trade sanctions, i.e. imposing a tariff or border tax on each imported good that is directly proportional to the carbon emitted during its production process. However, border tax adjustments hardly seem feasible in practice, as they would require a complete life cycle assessment for each single product that is imported. Otherwise, it seems highly likely that imposing uniform carbon tariffs on all goods from all countries that oppose climate protection could be seen as ‘arbitrary’ and ‘discriminatory’ under WTO rules. To circumvent this last problem, Ismer and Neuhoff (2007) propose that border tax adjustment should

focus on primary materials incorporated in imported products and, employing detailed data on production processes, assume that these products have been produced using the best available technology (BAT). However, it is not entirely clear how this proposal could be implemented in practice, what the implications for WTO law are, and how effective in reducing carbon leakage it could turn out to be.

Key lessons from the EU ETS[12]

The EU ETS runs in phases. Phase I (2005 – 2007) was planned as a test phase during which experience with the programme could be developed and banking of allowances was effectively not allowed. Phase II (2008 – 2012) coincides with the 5-year Kyoto commitment period. In line with the EU-wide Kyoto target, each Member state has its own national emissions target as defined by the EU burden-sharing agreement. Each Member state is required to develop a National Allocation Plan (NAP) which addresses the national target in two steps. First, it splits the national reduction burden between ETS and non-ETS sectors, hereby setting the trading sector's cap. Second, it specifies how the allowances will be allocated to the sources in the trading sector.

Setting the cap

The EU-wide caps of Phases I and II where determined in a decentralized negotiation process between the EU Commission and Member state governments. The aggregation of national caps as specified in NAPs resulted in the EU-wide cap. The Commission had the powers to review NAPs and reduced 15 NAPs in Phase I by together 290 million tonnes annually. Although this cut aimed at enforcing scarcity in the system, Phase I caps were still too lax. NAPs were based on projected business-as-usual emissions, many of which have been overestimated due to the influence of firm lobbying and information asymmetries between companies and regulators. Covered sources in Phase I received emission permits for 2080 $MtCO_2$, while actually emitting 2020 $MtCO_2$ annually on average (EEA 2007). Hence, the number of allocated emission allowances exceeded verified emissions by roughly 60 $MtCO_2$. This figure only reflects allowances allocated for *free* to *existing* installations. Not included are allowances which were auctioned or part of Member states' new entrant's reserves. The quantity of excess allowances during Phase I was therefore even higher. When data on verified emissions for 2005 was released in April 2006, it became clear that allocated allowances exceeded emissions by at least 3%. As a result, the price of Phase I EU Allowances (EUAs) crashed immediately and eventually fell below EUR 1 per tonne of CO2 in 2007).[13]

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[12] The following discussion is largely based on the findings provided by Convery et al. (2008)

[13] Note that in the presence of banking between trading periods, the price would not have crashed to zero since

The extent of cap mismatch in regard to emissions varied from country to country. From 2005 to 2006, only five countries faced a net shortage of allowances: UK (-83 Mt Co2), Italy (-33 Mt), Spain (-25 Mt), Ireland (-6 Mt), and Austria (-1 Mt) (Convery et al. 2008). The net position is here defined as the difference between allocation and emissions balance. In contrast, in eleven countries, eight of which were new Member states, allocations exceeded emissions by more than 10%. The differences in allowance allocation had distributional impacts, transferring money from countries with tight caps to countries with lax caps. Given the overall surplus in Eastern Europe, Convery et al. (2008) estimate that facilities in Western countries acquired allowances for 41 Mt CO2, worth EUR 700 million.

As a result of the overallocation in Phase I, the European Commission tightened the carbon constraint for Phase II. NAPs were downsized by the Commission, in some cases to a considerable extent. In relative terms, the Baltic States had to reduce their proposed caps by the highest percentages: Estonia -48%, Latvia -56%, and Lithuania -47%. In absolute terms, the caps for Poland (-76 MtCO2), Germany (-29 MtCO2), and Czech Republic (-15 MtCO2) were cut most. Overall, the Commission fixed the EU-wide cap at 2.08 billion tCO2 annually for the period of 2008-2012. That is 9.5% lower than the cap in Phase I.

Setting the post-2012 regime of the EU ETS, the EU adopted a revised EU ETS Directive in December 2008 which attempts to incorporate many of the lessons learnt during Phases I and II (EC 2008).[14] The directive for Phase III (2013 - 2020) includes several changes. Total EU trading sector emissions in 2020 will be reduced by 21% below 2005 levels, resulting in a cap of 1720 million tonnes CO_2.[15] To arrive at this quantity the centrally set EU-wide cap, which replaces the 27 NAPs, decreases annually by 1.74% from 2013 onwards (taking 2010 as basis year). This linear reduction factor is set to apply beyond the end of the third trading period and may be reviewed by 2025 at the latest.

The scheme's coverage will be extended to new sectors and new gases. It will cover CO_2 from emissions from aviation, petrochemicals, ammonia and aluminium, as well as N_2O emissions from the production of nitric, adipic and glyoxylic acids and perfluorocarbons from the aluminium sector. Road transport and shipping remain excluded, although the latter is likely to be included at a later stage. Agriculture and forestry are also left out. To lower administrative cost, smaller installations, emitting under 10,000 tonnes of CO_2 per year, will be allowed to opt out from the ETS, provided that alternative reduction measures

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overallocated allowances could have been used in phase 2 or phase 3, However, banking was not allowed. This illustrates the role of banking in containing price volatility.

[14] Table in the Appendix summarizes the main innovations of the draft directive and puts them into perspective with the current trading regime. Their final validation will depend on the results of the negotiations among the European Commission, Council and Parliament. Political consensus is expected to be achieved in December 2008.

[15] The numbers are based on the scope of the ETS as applicable in Phase II.

are put in place. Industrial greenhouse gases prevented from entering the atmosphere through the use of so-called carbon capture and storage (CCS) technology are to be treated as not emitted under the new scheme.

Allowance allocation

The current primary allocation method in the EU ETS is to grandfather allowances to sources for free. Most member states made no or only little use of the possibility of auctioning up to 5% of allowances in Phase I and 10% in Phase II. Only four countries used auctioning in Phase I, accounting for 0.13% of total allowances. More allowances are being auctioned in Phase II, though the expected quantity is still well below the 10% limit. Grandfathering was mainly based on historical emissions although benchmarking had been strongly advocated. Convery et al. (2008) assume that governments decided against benchmarks because they would have resulted in allocations too far below recent emissions to gain stakeholder acceptance.[16] The use of benchmarks has spread in Phase II, mainly in the power sector, but they are typically fuel specific, that is, different for power plants generating electricity from natural gas and coal.

The power sector has been allocated almost all of the aggregate ETS sectors' emission reduction burden in Phase I, resulting in a net short position in emission allowances (Convery et al. 2008). A sector's net position is here defined as the difference between gross long (allowances received) and gross short (actual emissions) position. The industrial sector, in particular iron and steel, was long in allowances. The privileged treatment of industry can be explained by the general assumption of the sectors' relatively lower abatement potential and exposure to non-EU competition.

All Member states created reserves which grandfathered allowances to new entrants. Most required closed installations to forfeit post-closure allowances. This measure was adopted for political reasons. The EU as an investment location should not be disadvantaged and the incentive to close facilities and move production elsewhere should be eliminated (Convery et al. 2008). The main effect, however, was to preserve pre-policy incentives to invest in existing (i.e. relatively polluting) facilities. Even though the perverse incentives of this provision were widely recognized, it was apparently not possible to resist political demands.

The decision to grandfather permits generated substantial windfall profits (i.e. additional revenues) for incumbent firms, especially in the power sector. Auctioning allowances would recover the scarcity rent from private companies for public use without impacting electricity prices relative to the free allocation case. On these grounds, the auctioning will be the principal allocation method in Phase III. The power sector will face full auctioning of permits from 2013 onwards (may be delayed until 2020 in some Eastern European countries), while

[16] In the EU ETS, choice of allocation method rests with national governments.

auctioning in all other sectors is to be phased-in incrementally, starting with 20% in 2013 and reaching 100% auctioning by 2025 at the latest. Industries which are at risk of carbon leakage may be exempted from this rule. For these industries free allocation will be based on a sector-specific benchmarks. Benchmarks will be based on the top 10% most efficient facilities in the relevant sector. The European Commission will determine in December 2009 which sectors are exposed to the risk of carbon leakage.

The total quantity of allowances that member states will auction will be determined on EU level, but auctions will be organised at country level. The Directive foresees that 88% of the total quantity of allowances to be auctioned is distributed according to the relative share of 2005 emissions in the EU ETS. For reasons of "fairness and solidarity", 12% of the total quantity of allowances to be auctioned will be redistributed to poorer member states.

Did abatement occur?

In light of the excess supply of allowances in Phase I it appears questionable whether the EU ETS was able to encourage CO_2 abatement. For the year 2007, when the EUA price dropped to a negligible level, the answer to this question is probably negative. Prior to this period, however, the EUA price consistently stayed above EUR 6 per tCO_2 and abatement should have occurred. Ellerman and Buchner (2008) estimate that for 2005 and 2006 the EU ETS reduced EU-23 emissions by between 50 and 100 $MtCO_2$/year. This is 2.5% to 5% less than the emissions expected in a scenario without EU ETS. The authors argue that the finding is valid in spite of the over-allocation which effectively existed in some countries and sectors. It is not the initial allocation that causes a source to reduce emissions but the price it must pay for its emissions, even if in opportunity cost terms. The authors, however, emphasize that this estimate should be treated with care because there exist many potential pitfalls in constructing counterfactual scenarios. A strong argument can be made that the baseline data used for establishing their scenario without EU ETS is biased. Other studies show lower estimates for induced abatement. Delarue et al. (2008) constructed a computer model in order to explore the potential of short-term CO_2 abatement in the European power sector. They think that fuel switching reduced EU-23 emissions by 35 - 64 $MtCO_2$ in 2005 and 19 - 25 $MtCO_2$ 2006, with more weight being given to the lower bounds. The European Environment Agency (EEA 2007) expects that reductions induced by the EU ETS by 2010 will be at least 150 $MtCO_2$ annually in the EU-15 and contribute 3.4 percentage points to their Kyoto-target of -8% relative to 1990 levels. For the new member states estimates differ greatly, depending on the method used to calculate the baseline. The mid-case scenario predicts EU-12 emission reductions of approximately 25 $MtCO_2$/year by 2010. Overall, the EU ETS is expected to reduce 2010 EU-27 CO2 emissions by 200 $MtCO_2$/year relative to business-as-usual.

Besides its extent, researchers also investigate the nature of abatement. Convery et al. (2008) found that abatement often occurred where it was not expected. In Germany, the power sector shifted generation from higher emitting lignite to lower emitting hard coal. In

the UK, there was a noticeable improvement in the carbon efficiency of coal-fired power plants, probably via increased use of biomass or improved energy efficiency. Analysts, however, predicted more reductions from substituting coal with natural gas. The authors argue that this did not happen in the magnitudes expected, largely because of the relatively high natural gas prices during 2005 and early 2006. In contrast, little attention had been given to either the German intra-fuel switch or the improved CO_2 efficiency observed in the UK. This underlines that market instruments may trigger abatement in areas where it was not anticipated by regulators.

Price effects

Looking at the interaction of carbon and electricity prices, there is no universal answer on how the EU ETS has affected electricity prices (Reinaud 2007). Many other factors affect generation prices such as high natural gas prices in 2005. Gas-fired power generation is increasingly the choice of investors in volatile markets due to short lead times and flexibility advantages. With gas thus being the marginal fuel for peak production, the interaction between gas and electricity prices is particularly close. The potential use of market power by electric utilities further complicates the picture. Moreover, as no data can be gathered on the bidding strategies, and the marginal supplier to the market, determining the precise level of pass through of CO_2 prices in electricity prices is not possible. Nevertheless, several studies attempted to provide estimates of pass through rates: Sijm et al. (2006) find rates ranging from 39% – 73% for Germany and the Netherlands for the period January to July 2005 and from 60% - 80% percent for the same countries between January to December 2005. For the reasons cited above, however, these estimates need to be treated with care.

Carbon market governance

The development of the European carbon market poses new challenges to institutions and governance. Two general areas of activity can be differentiated here: the monitoring and management of carbon markets.

Monitoring is necessary to ensure that allowance markets work efficiently. In the EU ETS, more than 10 million allowances are traded weekly on average, resulting in a market worth several billion Euros. The legal nature of these allowances is, however, unclear. Some countries consider them to be financial instruments whose trading is supervised by the financial service authority, while other countries consider them to be normal commodities and only their derivatives are viewed as financial instruments (EEA 2007). In order to avoid market manipulation and inside trading, it is important to consider how to apply the rules for financial markets to emission allowances. Furthermore, publication of market sensitive information by the Commission and Member states should be strictly and clearly regulated, since the release of market sensitive data impacts allowance prices. The same rules that regulate the dissemination of stock market sensitive information should apply here. In the

future, carbon market governance bodies might be responsible for collecting information on market transactions, analysing their impact on the economy and industrial sectors, and disclosing this information in a predictable and transparent manner.[17] They would also act to uncover and abolish market manipulations (e.g. by coordinating national and regional market control authorities), organise permit auctions, and administer the overall allocation process.

The second, more controversial area of activity regards the intervention in carbon markets. The Australian ETS, for instance, will feature an "Independent Carbon Bank" which would be in charge of regulating the carbon market based on the rules provided by the legislator (Australia 2008).[18] Depending on the specific proposal, the carbon bank may adjust the limits on the use of offsets, extend the possibility of banking/borrowing, set the interest rates for borrowed allowances, or even sell/buy additional allowances. Though these measures may provide near-term flexibility and cost relief, the long-term reduction trajectory and emission cap may be hampered. For this reason, relief measures should only be employed incrementally after in-depth consideration of market conditions and be accompanied by a clear repayment schedule for borrowed allowances. The advantages of an intervening carbon bank can be questioned. It can be argued that the existence of a carbon bank creates uncertainty over allowance quantities if it has the power to temporarily adjust caps and borrowing modalities. Carbon prices and investments in low-emission technologies become less certain than, for example, in a fixed safety valve approach (see section 0). Further, market participants might decide to delay abatement actions because they speculate on a loosening of the carbon constraint by the intervening bank. It also exists the danger that borrowed quantities are cancelled by an eventual adjustment to the cap. Nevertheless, carbon banks might satisfy politicians' and investors' demand for flexible carbon constraints and therefore represent a possible measure to provide short-term cost relief. The optimal layout and operating principles of carbon banks are subject of ongoing research.

Complementary measures

Environmental policies are often directed at internalizing externalities. The standard theory of externalities indicates that only one instrument is needed to internalise one externality. In some instances, however, multiple externalities and market failures exist, and it is very unlikely that one instrument can be used to optimally address several market failures simultaneously. Therefore, several complementary instruments are required.

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[17] Several companies have emerged providing market data, projections and background information on the EU ETS (see for example. www.pointcarbon.com).

[18] The Carbon Market Efficiency Board mentioned in Footnote Error: Reference source not found is another example for a carbon market oversight institution.

In Section 0, market failures were discussed that lead to negative abatement costs, mostly related to energy efficiency measures. It was concluded that full sectoral coverage along with complementary regulatory measures are needed to tap into this low-cost mitigation potential. Moreover, other market failures related to the specific circumstances of technological innovation exist which prevent the large-scale uptake of low-carbon technologies such as renewable energy. For this reason, it is of utmost importance to understand that even a well designed emissions trading system is not sufficient on its own to encourage the fundamental energy system transformation we aim for when giving carbon a price. Although many renewable energy technologies, given stringent carbon constraints, are likely to be profitable in the long-term, most of them fail to attract investments because of high initial costs. This is in spite of their significant cost-reduction potential due to learning processes and economies of scale (IEA, 2000).

The first source of failure in technology markets can be found in the public good nature of knowledge. The positive side-effects of introducing new technologies are not limited to the innovating firm, because technology development typically also creates benefits for others, e.g. in the form of knowledge spill-overs. In the energy sector in particular, technology spill-over to competitors is large and, as a result, firms under-invest in research and development (Azar and Dowlatabadi 1999). Without additional policies addressing this externality, investments remain lower than socially desirable even in presence of an optimal carbon price.

Second, learning and network effects introduce multiple equilibria to the energy-economy system. In the status quo, marginal additional investments in many low-carbon technologies do not achieve profitability even though a price on carbon exists because many alternative technologies are still at the beginning of their learning curves. This state is a stable equilibrium. On the other hand, once a technology reaches a higher point on the learning curve, another stable state may be reached, one with high deployment of low-carbon technologies that is cost-optimal even if R&D and learning investments are taken into account. This bistability creates a strong path-dependency and potential technology lock-in which need to be addressed e.g. via feed-in tariffs or renewable energy quotas (see Box 1).

Third, energy infrastructure investments compete for capital with other investment opportunities, and thus will be considered attractive only if they provide satisfying returns on investment in the near-term. The benefits of research in new energy technologies, however, may not be realized for two to three decades, which is beyond the planning horizons of even the most forward-looking companies (Anderson and Bird 1992).

Fourth, large uncertainties exist which concern the future development of energy and climate policy, availability and prices of fossil fuels, as well as the speed of innovation in low-carbon technologies. Investors, being risk averse, fear the threat of stranded investments and consequently tend to delay future engagements. This is particularly damaging for many low-carbon technologies, since they are rather capital intensive and require substantial up-

front expenditures.

Overall, none of these market failures is adequately addressed by an emissions trading system alone. Complementary measures and policies such as feed-in tariffs or quotas for renewable energy sources are required to support the transformation towards a low carbon economy. At the same time, existing subsidies for unsustainable and carbon-intensive energy sources such as coal need to be abolished as they represent negative carbon prices. This may free-up resources which can then be spent on low-carbon technologies. In some circumstances, complementary measures may be transitional because although they may be necessary to address a specific failure in the short- to medium-terms they are not expected to be helpful in the longer term. They can support and drive research, development and demonstration of new technologies where the investors are unable to capture the full benefits of their investment and address other market failures, such as non-price barriers.

Box 1: Renewable energy support policies in Europe

Among renewable energy support policies one can distinguish between investment support (e.g. capital grants, tax exemptions or reductions on the purchase of goods) and operating support (e.g. price subsidies, green certificates, tender schemes, tax exemptions or reductions on the production of electricity). In the EU, operating support plays a far more important role and can either work through prices or quantities. Although, in theory, both price and quantity-based instruments should yield the same economic efficiency (see BP1), practical experiences with renewable support policies in Europe draws a different picture.

A study prepared for the European Commission assessed renewable electricity support policies in various EU member states and concludes that for onshore wind, for example, in 2006 well-adapted feed-in tariffs were typically more effective at a relatively lower producer profit (Ragwitz et al. 2005). In other words, it can be observed that quota systems achieved a rather low effectiveness at comparably higher profit margins. However, it should be noted that quota systems are relatively new instruments, and there is at present little knowledge of how the certificate prices will develop over time. Nevertheless, quota systems generally involve a higher price uncertainty which lead to high risk premiums and limited economic efficiency from a social planer perspective. They also are less capable to differentiate between technologies. For these and other reasons, feed-in tariffs, though they too have disadvantages, achieved better results in promoting renewable energies in Europe than quota-based policies.

Conclusions

Emissions trading is expanding world-wide. Cap-and-trade systems effectively establish a price on carbon by setting an absolute quantitative limit for greenhouse gas emissions. The allowance cap determines the carbon price and the instrument's environmental

effectiveness. But uncertainty over the carbon price makes it difficult to estimate the policy's economic cost. Trading of permits enables participants to reduce emissions where this is cheapest and leads to the formation of a price signal reflecting marginal abatement costs across covered installations. Looking at the EU ETS experience, one can draw several conclusions in regard to general ETS design:

ETS coverage, both in terms of sectors and gases, should be as broad as possible in order to maximise market liquidity and the range of potential abatement options. Sectors with highly dispersed emission sources (e.g. transport) should be covered upstream in order to keep transaction cost low. Sources which are difficult to measure and monitor (e.g. agriculture) should be excluded from coverage to safeguard the cap's environmental integrity. In such sectors, domestic offset credits may be used to smooth the transition towards broader trading regimes by allowing experience learning with monitoring emissions. Setting and communicating long-term trajectories for cap and coverage is of paramount importance for enhancing predictability and investor's confidence.

The allocation of allowances affects the policy's distributional impact and cost-effectiveness. The EU ETS allocation process demonstrated that free allocation can significantly distort incentives but may ease the transition to emissions trading. Increasing the use of auctioning is likely to generate benefits in terms of cost-effectiveness, distribution, and public finances. Allocation procedures can be used for redistributing wealth to underprivileged regions. New entrants provisions should be carefully balanced to set reasonable incentives while avoiding to shield incumbents against new competitors. Different allocation methods can apply to different sectors, mirroring industries' diverse vulnerabilities to carbon pricing and international competition.

Banking provisions can provide significant temporal flexibility, reducing cost and volatility. The benefit of borrowing provisions is more ambiguous as concerns over time-consistency exist. No existing trading system allows for borrowing and further research needs to clarify the conditions under which it might represent a sensible design choice.

Price ceilings limit the potential range of allowance prices. On one hand, this reduces cost uncertainty, on the other hand, it can diminish the incentive for investors to develop low-carbon technologies. In addition, price bounds complicate linking up with other trading systems.

Monitoring, reporting, and verification of emissions is critical for ensuring a trading system's transparency, integrity, and credibility. Reliable historic data is essential for determining caps at appropriate levels. Stringent verification rules can avoid market-distorting ex post corrections and enhance investors' trust carbon markets. Institutions need to be put in place which oversee the carbon market and ensure that it is functioning efficiently.

Overall, carbon pricing alone is not enough to mitigate climate change. The standard theory of externalities indicates that only one instrument is needed to internalise one externality. In

some instances, however, multiple externalities and market failures exist, and it is very unlikely that one instrument can be used to optimally address several market failures simultaneously. Policy makers need to implement complementary measures which address other market failures such as underinvestment in technological innovation.

Appendix

Table 1: Comparison of different cap-and-trade programmes (adopted from Flachsland et al. 2008)

	EU ETS	RGGI	California	Australia	New Zealand
Implementation stage	Up and running since January 2005	Legislation process in progress	2007 Proposal by MAC expert commission	2007 Discussion paper by PM Task Group expert commission	2007 Final Decisions on the core design and on detailed design features on the government level
(Envisaged) Start Date	1 January 2005	1 January 2009	1 January 2012	Scheduled in 2011, or 2012	Stage 1: 1 Jan 2008 Stage 2: 1 Jan 2009 Stage 3: 1 Jan 2010 Stage 4: 1 Jan 2013
Ratification of Kyoto Protocol	Yes	No	No	Yes	Yes
Participating Sub-regions	27 EU Member States	10 U.S. states: Connecticut, Delaware, New Jersey, New York, Maine, Maryland, Massachusetts, New Hampshire, Rhode Island, Vermont	California	Australian Commonwealth	New Zealand
Regulated Sectors	Electricity, refining, iron & steel, cement, glass, ceramics, pulp and paper	Electricity generating facilities ≥ 25 MW primarily fired by fossil fuels (coal, natural gas, oil), feeding more than 10% of their generated electricity into the grid	Pr 1: Electricity, refining, cement, other processes, non-CO2[19] Pr 2: like 1, + transport Pr 3 & 4: like 2, + small industry, commercial, residential sources	Electricity and industrial processes emitting more than 25 kt CO2eq per annum, transport, waste to be discussed	S1: Forestry S2: Liquid fossil fuels S3: Stationary energy; industrial processes S4: Agriculture; waste
Regulated Emissions	CO2 only	CO2 only	CO2, N2O, HFCs, PFCs, and SF6	CO2, CH4, N2O, HFCs, PFCs, and SF6	CO2, CH4, N2O, HFCs, PFCs, and SF6
Point of Regulation	Downstream	Downstream	Up- and Downstream	Up- and Downstream	Up- and Downstream
Covered Emissions (Mt CO2eq)	~2.000 Mt	149 Mt (2003)	Pr1: 193Mt Pr2: 356Mt Pr3&4: 409Mt	~ 300 Mt (according to calculations by PM Task Group)	S1: 21.8 Mt (expected for the period 2008 – 2012) S2: 15 Mt (2005)

[19] The Market Advisory Committee has proposed four program options (abbreviated Pr here) with differing coverage and point of regulation

	EU ETS	RGGI	California	Australia	New Zealand
					S3: 22.8 Mt (2005) S4: 39.2 Mt (2005) Total: 77.6 Mt (excluding S1)
Share of economy-wide emissions (CO2eq)		~ 24%	Pr1: 39% Pr2: 72% Pr3&4: 83%	~55%	S1: N/A S2: 19% S3: 30% S4: 51%
Number of covered entities	~10.000	~630	Pr1: ~450 Pr2: ~480 Pr3: ~490 Pr4: ~150	~ 900	S1: ≥ 1000 S2: ~5 S3: ~ 80 (~45 stationary energy; ~ 35 industrial processes) S4: ≥ 35 agriculture (Point of Regulation for agriculture not decided); ~ 60 waste
Total Emissions (incl. non-energy emissions) in Mt CO2eq	4979.4 (in 2004, EU25)	624.9 (in 2003)	494.3 (in 2004)	525.4 (in 2005)	77.2 (in 2005) + deforestation
Energy mix by sectors	Industry: 28% Households: 41% Transport: 31%	Industry: 17.5% Commercial: 25.9% Households: 27.5% Transport: 29%	Industry: 23% Commercial: 18% Households: 18% Transport: 40%	Industry + Commercial: 50% Households: 30% Transport: 20%	Industry: 30% Commercial: 9% Households: 13% Transport: 44% Agriculture: 4%
Energy mix by fuels	Oil: 37% Solid Fuels: 18% Natural Gas: 24% Nuclear: 15% Renewables: 6%	Petroleum products: 48.9% Coal: 8.6% Natural Gas: 23.2% Nuclear: 11.7% Renewables: 7.1%	Petroleum products: 46% Coal: 8% Natural Gas: 29.5% Nuclear: 5% Renewables: 11.5%	Oil: 35% Coal: 41% Natural Gas: 19% Nuclear: - Renewables: 5%	Oil: 38% Coal: 13% Natural Gas: 20% Nuclear: - Renewables: 28%
Historical emission trends	EU25: 8% below 1990 levels in 2003; EU15: 1.7% below 1990 levels in 2003	+7.4% during 1990-2003 period	+14.3% during 1990-2004 period	+4.5% during 1990-2005 period	+23.4% during 1990-2005 period
Future Projections	4.7% above 1990 levels in 2030	12% above 1990 levels in 2019 (electricity only)	40% increase in 1990-2020 period	27% above 1990 levels in 2020	30% above 2005 levels in 2030
Reduction goals	- 8% below 1990 levels in 2008-12 period - 20% (or 30%) below 1990 levels in 2020 - 60%-80% below 1990 levels by 2050	- 2009 cap: 5% above 2005 levels, will remain until 2015 - 10% reduction below this cap by 2019	- 2000 levels in 2010 - 1990 levels in 2020 - 80% reduction below 1990 levels	8% above 1990 levels in 2008-12 period	Carbon neutrality: - Electricity by 2025 - Stationary energy by 2030 - Transport by 2040

	EU ETS	RGGI	California	Australia	New Zealand
			by 2050		
Unit of Measurement	1 metric tonne CO2eq	1 short tonne CO2eq (1 short tonne equals 0.90718474 metric tonnes)	1 metric tonne CO2eq	1 metric tonne CO2eq	1 metric tonne CO2eq
Cap	Future levels not specified. Bottom up emergence of cap through NAP negotiations. Plans for centrally set cap.	Annual Cap of 170.6 Mt CO2 between 2009 and 2014; annual reduction of 2.5% between 2015 and 2018	Not specified	Not specified	To be linked to NZ commitments under the Kyoto protocol (309.5 Mt in 2012) and an international post-2012 regime, respectively
Allocation Method	Grandfathering, benchmarking, max. 10% auctioning	Auctioning minimum 25%; decision over remaining 75% left to individual states	Auctioning and benchmarking	Free allocation and auctioning	S1: Free allocation S2: Auctioning S3: Some free allocation for industrial processes S4: 90% free allocation for agriculture
Banking	From 2nd Period on: Unlimited	Unlimited	Unlimited	Limit proposed as long as price cap applies	Unlimited
Borrowing	Rejected	Rejected	Rejected	Rejected	Rejected
Trading Period	3 years in first period, 5 years in second	3 years	No specification	10 years	2008/9/10 - 2012 2013- 2020
Compliance Period	1 year	3 years	3 years recommended	1 year recommended	1 year (S1: initially 2 years)
Price Cap	Rejected	Two stage safety valve arrangement: "Credits Trigger Event" if spot price for emissions exceeds $ 7 for a period over 12 months; "Safety Valve Trigger Event" if spot price for emissions exceeds $ 10 for a period over 12 months	Rejected	Proposed; further specifications to be discussed	Rejected in principal, but considered if no international climate policy agreement post-2012
Price Floor	No	Yes	Encouraged for Consideration	No	No
Penalty System	Delivery of the non-delivered allowances + € 100 penalty per tonne (2008-2012)	Three times of the non-delivered certificates to be delivered at next compliance date	Not specified, but non-delivery shall be made up + penalty	Emissions fee proposed setting a price cap	Delivery of the non-delivered allowances (can be extended to two times of the non-delivered allowances) + NZ$ 30 – 60 penalty

	EU ETS	RGGI	California	Australia	New Zealand
					per tonne
MRV	Updated in 2007	Guidelines for continuing measurement based on CRF 40 Part 75 (Acid rain program regulation) that demands a maximum uncertainty of 10%. Verification by regulating authority.	To be developed, building on existing MRV infrastructure of CCAR	To be developed	To be developed
Registry	Community Independent Transaction Log (CITL) overseeing communications between national registries	No common registry for RGGI	To be developed, building on existing CCAR infrastructure	Under development; rules clarified under the Australia National Greenhouse and Energy Reporting Act in legislation since September 2007	To be developed building on existing infrastructure established under the Climate Change Response Act (CCRA) 2002
Domestic credit programme	No	Credits are accepted from programs in RGGI states or any other U.S. state or jurisdiction.	To be developed using RGGI experience; programmatic approach proposed	To be developed especially focusing on forestry and agriculture	Discussed
Eligibility of CDM/JI	Yes	Generally no; In case of a safety trigger event credit allowances may be awarded for the retirement of allowances or credits from international trading programs	Most MAC members recommend eligibility of CDM	Yes	Yes, + AAUs
Import Quota for Credits	Varying from country to country according to set of criteria. Average (weighted) EU quota for CDM/JI import in trading period II: 13,4%	3.3% of a facility's emissions can be covered by credits; the number rises up to 10% in case of a safety valve trigger event	Most MAC members recommend unrestricted credit import	No	No

Table 2: Revision of EU ETS Directive in perspective (adopted from Mission Climat 2008)

	2005 - 2007	2008 - 2012	Proposal for 2013-2020	
	Directive 2003/87/CE and 2004/101/CE		Draft COM(2008)16 final	
Perimeter	EU25 + Bulgaria and Romania in 2007	EU27 + Norway, Iceland and Liechtenstein	EU27 + Norway, Iceland and Liechtenstein Possibility of linking the EU ETS to other national or regional cap-and-trade systems	
	CO_2 only	CO_2 ; + N_2O in France and the Netherlands	CO_2 + N_2O and PFC	
	50% of allowances allocated to electric power producers, 50% of allowances allocated to other combustion activities (including refining), cement, steel, glass, ceramics and paper producers	Same sectors as 2005-2007 + aviation beginning in 2012	Same sectors as 2008-2012 + aluminum and ammonia production. Discussion of the inclusion of maritime shipping	
Capping of emissions	National (NAP validated by the European Commission)		European cap, with auctioning quotas distributed among States on the basis of their historical emissions in 2005 and their economic situation	
	2,300 million allowances annually (including reserves of 70 Mt/year)	2,100 million allowances annually (including reserves of 120 Mt/year, non-constant perimeter)	Without an international agreement:	With an international agreement:
			-20 % over the period 2013: 1,970 Mt 2020: 1,720 Mt	-30 % over the period 2013: 1,870 Mt 2020: 1,375 Mt
General allocation procedures	Free for at least 95% of allowances. Less than 1% of the allowances were effectively auctioned (principally Denmark, Hungary and Ireland).	Free for at least 90% of allowances. Auctions planned for at least 3% of the allowances (principally Germany, United Kingdom, Netherlands and Hungary)	Auctioning of all allowances beginning in 2013 in the electric power generation sector. Linearly increasing auctioning in the other sectors (beginning at 20% in 2013 and reaching 100% in 2020)	
	Essentially free allowances		Essentially auctioned allowances	
Allocation to new entrants	Reserves of allowances and national allocation method		European reserve and allocation method on the basis of harmonized rules	
	70 Mt/year	120 Mt/year		
Kyoto carbon credits (CER and ERU)	Permitted, nut not used due to overallocation	Utilization limited to 13.5% of the allocation on average (from 0 to 20%, depending on the country) Total maximum import of 1.4 billion credits, i.e. 280 Mt/year	Without an international agreement: Possible use of unrestored surplus of 2008-2012 credits for compliance	With an international agreement: 2008-2012 surplus + volume equal to 50% of the additional effort required
Other carbon credits			Possibility of creating harmonized European domestic offset projects or other types of international projects	
Distortion of competition with non-EU countries	Handling by the States via the rate of effort applied to each sector in the NAP. Principal effort by the electric power generation sector, which is subject to relatively little international competition.		If necessary, the Commission will propose the continuation of free allowances in certain sectors, or some other mechanism of the border tax adjustment type	
Registry	National registries + European registry (CITL)		European registry only	

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3 Credible commitment in carbon policy

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Abstract

In this article the problem of credible commitment in carbon policy is discussed. Investors favour long-term predictability of the policy but without any external enforcement mechanisms a commitment made by a government can be withdrawn, leading to scepticism and lack of credibility. This results in increased market risks and investment hold-up. Regulatory uncertainty stems from (i) strategic interactions between government and firms, (ii) potential learning about climate damage and abatement cost, and (iii) political volatility. While commitment to future policy encourages private investment, it also imposes costs in the form of reduced flexibility to accommodate new information or preferences. The article reviews devices that may help policymakers to raise the level of commitment while also leaving some room for flexible adjustments. In particular, legislation of a long-term governance framework, delegation to an independent carbon agency, and securitization of investors' stakes in emission markets offer palliative approaches.

Introduction

If a government unilaterally introduces a carbon price and commits itself to this policy for the foreseeable future, then firms will react to this by incorporating the expected price in their investment decisions. Yet, rational actors will discount the expected carbon price and will do so even more when it is felt that the government might not stick to its self-imposed commitment. Firms will either postpone investing until uncertainty regarding future carbon policy is resolved or require higher rates of return. In both cases, this will reduce the total level of emissions abatement (IEA, 2007). Thus, the issue of how to internally strengthen commitment in order to gain credibility is vital for the effectiveness of carbon policy. At the same time, however, commitment imposes costs if there is uncertainty over relevant parameters such as climate change damage or abatement costs. Commitment then reduces the flexibility to adjust the policy according to new information. Thus, carbon policy is faced with a trade-off between valuable commitment and valuable flexibility.

The commitment problem in carbon policy has been widely discussed and there are many different views as to both its source and its 'solution'. For example, Helm et al. (2003) highlight time inconsistency as a source of the problem and propose that responsibility be delegated to an independent carbon agency, while Ismer and Neuhoff (2009) suggest using financial options to secure government commitment. In Section 2, a discussion of 'credibility' is given, while in Section 3 three sources of regulatory uncertainty regarding

carbon policy are distinguished and their implications for commitment are examined. In Section 4, the literature on commitment devices is reviewed and a conclusion is offered in Section 5. The main aim of this article is to present a synthesis of existing approaches for future research.

Sources of credibility

What is credibility? In our context, individuals, or a set thereof, have credibility if others believe that they will do what they commit to. A common scenario in carbon policy is for a government to announce that it will price carbon (e.g. by taxation or an emissions trading scheme) over a future period in order to encourage emissions abatement by firms. Firms will assess the credibility of the government's announcement and chose their level of investment accordingly. Credibility is hence a vital element of intertemporal transactions where actors move sequentially.[20] The assessment by firms does not entail a binary choice but rather extends along a continuum between perfectly credible and perfectly incredible. The level of perceived credibility by a firm depends on the government's observable incentives. Assuming that the government acts in its self-interest, the more the observable gains from compliance outweigh the observable gains from deviation, the more credible a policy is. Following Forder (2001), it is assumed that two main factors that determine the level of incentives and perceived credibility are: (1) reputation and (2) commitment devices.

Repetition and reputation

A government can build up the reputation of credibility through a history of compliance in political transactions. This reputation can be treated like a capital asset that both needs investment (refraining from opportunism) and also pays a yield (Dixit, 1996). Since credibility leads to lower risk, higher private investments and growth (North, 1993), this yield consists in the government's ability to secure better outcomes for the economy. If the incentives of repetition and reputation are strong enough, no additional measures are needed (Persson and Tabellini, 1994).

Making binding commitments

Where reputation is lacking or low, credibility can be deliberately engineered or improved through forming various ties and bonds known as 'commitment devices'. Kydland and Prescott (1977, p.487) describe them as 'institutional arrangements that make it a difficult

[20] A government that could move first - for example by paying the firm a subsidy for emissions abatement upfront - would need to worry less about credibility (Abrego and Perroni, 2002; Ulph and Ulph, 2009; Golombek et al., 2010). As Schelling (1956, p.283) writes, "what is the best way to persuade someone of his/her intention? 'Make it true'."

and time-consuming process to change the policy rules in all but emergency situations'.[21] Before these institutional arrangements are discussed in detail below, three principle dimensions of commitment are first distinguished:

First, an institutional arrangement or commitment device (we use the terms interchangeably) can be either external or internal to the jurisdiction undertaking the commitment (Ismer and Neuhoff, 2009). An internal arrangement primarily binds a government vis-à-vis its regulated subjects (a vertical hierarchy), while an external arrangement primarily binds a government vis-à-vis other governments (a horizontal hierarchy). The analysis here focuses on internal commitment devices because external devices, such as multilateral environmental agreements (MEAs), depend on the feasibility of international cooperation. Hence, external devices are beyond any single government's control. Nevertheless it is important to understand that an external device could considerably improve the credibility of commitments vis-à-vis internal stakeholders (Conconi and Perroni, 2009). In the case of non-compliance, the MEA might introduce certain penalties, providing a government with an external incentive to honour its internal obligations. However, as the experience with the Kyoto Protocol demonstrates, devising a self-enforcing international climate treaty is a challenging task (Barrett, 2003).[22] Even if sustained global cooperation were eventually achieved, an international agreement on carbon constraints would still require their transcription into national policies. Hence, the issue of how to strengthen commitment internally, i.e. using devices that bind policymakers within their own jurisdiction, is of great importance.

Second, a commitment may be credible in a motivational or an imperative sense (Shepsle, 1991). A commitment is motivationally credible if the observable gain from deviation from it is below the observable gain from compliance. While motivational commitment devices do not rule out deviation per se, they introduce additional costs for potential defectors making deviation less profitable and hence less likely. By contrast, a commitment is imperatively credible if actors are not free to act otherwise because compliance is coerced. A popular example of an imperative commitment is Ulysses, who bound himself to a mast in order to

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[21] Bryan et al. (2010) point out that these arrangements do not serve a strategic purpose with respect to others but rather help the agent to fulfil his own future plans. Schelling (1954, p.282), by contrast, discusses commitment in an explicit strategic context where 'the power to constrain an adversary may depend on the power to bind oneself'. Strategic commitment devices are designed to help players win a bigger share of the relevant pot, while efficiency-enhancing commitment devices are designed to increase the size of the relevant pot.

[22] Note that the quality of enforcement mechanisms varies over issue areas. The Montreal Protocol on ozone depleting gases is widely considered as a successful MEA with good enforcement mechanisms. However, designing a self-enforcing global climate change treaty seems more challenging for a number of reasons (for a detailed analysis see Barrett, 2003). Note that linking regional emissions trading systems could provide an alternative source of external commitment because linking agreements can curtail the flexibility for unilateral adjustments to carbon pricing (Flachsland et al., 2009).

resist the lure of the Sirens' song on his future self (Elster, 1977). Ulysses committed to resist their song, while the fetters around his wrists forced his compliance. However, unlike Ulysses, a sovereign state - one who owns the monopoly for using ultimate force - cannot be coerced to honour its commitments (an exception is when actors are prepared to go beyond political deliberation by entering the realm of war). Hence, commitment in public policy can only be of the motivational kind.

The case of Ulysses and the Sirens also illustrates the third dimension of commitment: autonomous or heteronomous commitment. A commitment is autonomous (or self-binding) when the agent (or set thereof) who forms a commitment to act is the main intended recipient or beneficiary (or set thereof) of the action itself: Ulysses commits himself to a course of action intended to prevent his future self from breaking his prior commitment (Schelling, 1984). Commitment in public policy, however, also needs to bind others (Alesina and Tabellini, 1988). A commitment is heteronomous when the agent making the commitment to act is not the intended recipient of the act itself. For example, constitutions are deliberately structured so as to be difficult to change by successive majorities (Holmes, 1988). Carbon policy obviously needs to provide for heteronomous kinds of commitment because climate change is a long-term issue and both the agent (e.g. current government) and the recipient (e.g. future government) will be composed of different sets of individuals at the time of performance.[23] Commitment devices hence provide successive majorities with an incentive to honour their predecessors' policies. While they foster trust in the regulatory regime, investment, and growth, commitment devices also carry costs. This trade-off is discussed in the next section, before turning to a discussion of individual commitment devices.

Sources of regulatory uncertainty

The benefits of commitment are not unequivocally positive but rather depend on the source of regulatory uncertainty considered. Rodrik and Zeckhauser (1988) argue that public policy in general suffers from a fundamental trade-off between valuable commitment and valuable flexibility (or 'responsiveness' as they call it). While Hovi et al. (2009) identify time inconsistency, international anarchy, and domestic politics as sources of uncertainty in climate change policy, they ignore the distinct trade-offs between flexibility and commitment. In our view, there are three main sources of carbon policy uncertainty and each of them implies different net-benefits of commitment. First, in a deterministic setting where government and firms interact strategically, government's ability to make binding

[23] If one views 'government' as referring to a unitary, eternal entity, commitment in public policy will appear autonomous as the institution 'government' binds its own hands. This is usually the perspective chosen by analyses of time-inconsistency problems. However, government is here regarded as a group of individuals whose composition and motives may change.

commitments improves outcomes whenever firms' anticipation of government's reaction may have adverse incentive effects. Second, with potential learning about climate change damages, abatement technologies, and international politics, commitment can impose costs as it reduces valuable flexibility to respond to new circumstances. Third, political volatility may be used as an argument for commitment but it raises questions of democratic legitimacy. These issues are discussed in detail below.

Strategic interaction between government and firms

Time inconsistent optimality

Analyses of the problem of time inconsistency began with the seminal article by Kydland and Prescott (1977) in the arena of macroeconomic policy, who demonstrated the conditions under which policymakers have an ex post incentive to renege on a policy that may have been optimal ex ante. Time inconsistency now is a widely discussed issue in the literature on optimal pollution control, though there is still no unified opinion on its origin and direction. While some authors identify redistribution as the source of the problem (Marsiliani and Renström, 2000; Helm et al., 2003; Baldursson and von der Fehr, 2008), others emphasize changes in marginal abatement cost curves (Biglaiser et al., 1995; Gersbach and Glazer, 1999). Some even predict higher ex-post levels of the optimal carbon price (e.g. Marsiliani and Renström, 2000), while others the opposite (e.g. Abrego and Perroni, 2002).

Consider a benevolent and omniscient government whose sole objective is the maximization of social welfare. This government commits ex ante to tax carbon emissions on the basis of which firms invest in low-carbon technologies. These investments generate sunk costs on the private sector side since firms are committed in virtue of their investments in factories, power plants etc., while the government is only committed in virtue of existing laws (many of which it can change). In pursuit of other goals, the government is tempted to exploit this difference by adjusting the policy ex post, for example, by reducing the carbon tax to a level which permits low-carbon energy providers to only cover their variable costs (Blackmon and Zeckhauser, 1992). The appropriated quasi-rent of sunk investments is then redistributed to consumers in the form of lower energy prices. Utilities in general, and the energy sector in particular, are vulnerable to ex post appropriation because plant value is highly dependent on location and use (Spiller, 1996).[24] It is assumed here that the reason for the impartial and benevolent government's policy change consists not in resolved uncertainty or shifts in political preferences (these issues are discussed below) but rather in the maximization of social welfare once investments are made. Either the government re-optimizes its policy ex-

[24] The incentive to appropriate is greater when the interval between investments is longer because the penalty for appropriation (higher future capital cost) has a lower present value (Blackmon and Zeckhauser, 1992).

post (time inconsistent) or maintains the now sub-optimal ex-ante level (time consistent). Hence, in this context, policy can be either optimal or time consistent but not both.

Investment hold-up

In order to achieve an optimal outcome, the government might try to 'fool' firms by first promising the ex ante policy before opportunistically adjusting the policy ex post. Of course, this strategy will only work with naïve agents. Rational agents who anticipate the government's incentive to renege might respond in several ways (Spiller, 1996): they can either postpone investment or require a higher rate of return to compensate for higher risk, or they can invest in areas where the payback period is relatively short. Moreover, firms may reduce maintenance expenditures or choose technologies that have a lower degree of specificity in order to reduce their exposure to governmental opportunism. This, however, reduces social welfare because less specific technologies are less well suited for their task and hence less efficient.

The risk premium firms demand, in the presence of regulatory risk, reflects the loss of the option value of being able to decide whether the investment should at a later stage be undertaken when additional information is available (Dixit and Pindyck, 1994). The value of that option increases with risk. For example, Blyth et al. (2007) have found that uncertainty regarding policy increases the carbon price required to stimulate investment in Carbon Capture and Storage by 16-37% compared to a situation of perfect policy certainty.

Ratchet effects

While having a flexible policy allows governments to pursue time inconsistent strategies against firms, firms can also try to exploit regulatory discretion to their own advantage. So-called 'ratchet effects' can occur if firms' current performance is used as a criterion for setting future policy targets (Weitzman, 1980). For example, consider the periodic update of emission caps in the EU Emissions Trading Scheme (EU ETS). Flexible caps provide firms with an incentive to distort investment decisions in order to signal high compliance costs and prepare the ground for a more lenient cap in subsequent trading periods (Harstad and Eskeland, 2010). A firm's chance of winning with this strategy increases with its market power. Moreover, the use of grandfathering will further aggravate dynamic incentive problems if allowance allocation is based on historical emissions (Hepburn, 2006). Regulated entities can seek to delay abatement or even exacerbate carbon lock-in in order to maximize the number of allowances received.

Regardless of whether firms or governments pursue opportunistic strategies, flexible policy carries the risk of distorting the incentives for emissions abatement. The mere potential for strategic interactions between government and firms, with firms having incomplete knowledge about the direction and extent of policy change, generates risks and reduces investments below socially optimal levels.

Uncertain damage and abatement costs

Given the potential costs of strategic interactions, the ability to commit is clearly valuable in a deterministic setting. Carbon pricing, however, has to deal with many unknowns. The best available estimates of benefits and costs of emissions abatement are likely to change over time. There are three main areas of positive (rather than normative) uncertainty.

First, the benefits of emissions abatement (mainly, avoided climate change damages) depend on multiple variables and links in the Earth system, none of which are perfectly understood today (IPCC, 2007a, 2007b). Second, the costs of emissions abatement are determined by the development and deployment of low-carbon or carbon-free technologies (IPCC, 2007c). For example, consider the unexpected arrival of a backstop technology which provides low-carbon energy in abundance and at low costs. The ex ante carbon price would need to be lowered to reflect cheaper abatement costs. (In the case of emissions trading, the cap would have to be tightened to achieve the new socially higher level of abatement.) If the policymaker was completely committed, significant economic inefficiencies could arise.

Third, the scientific uncertainty over climate damage and abatement costs is further exacerbated by uncertainty over international climate policy. Emissions abatement is a global public good and the net benefits of national carbon policy depend on the contribution of other nations to this. For example, consider the EU which has unilaterally committed to reduce emissions by 20% below 1990 levels by 2020. The EU expects that other regions and countries will eventually take on comparable burdens. However, if they choose instead to free-ride on EU efforts, unilateral abatement is likely to become very costly: carbon-intensive industries might relocate from the EU to countries with less stringent policies (carbon leakage) with the result that EU reduction efforts would yield little or no impact on global emissions.[25] The behaviour of other countries is therefore a key parameter in assessing the optimal level of national and regional carbon policy.

In sum, carbon policy deals with a so-called 'super-wicked problem' (Lazarus, 2009) that is characterized by deep uncertainties, many interdependencies, and complex social dynamics. Once more is learnt about these factors, carbon policy might have to change accordingly. Having the flexibility to update policy according to new discoveries is therefore valuable. However the existence of positive uncertainty rules out any easy way to distinguish opportunism from reasonable responses to changed circumstances. For example, it may not always be possible for a government to determine whether higher than expected abatement costs are a consequence of strategic moves on the private sector side or simply a bad state of nature (Rodrik and Zeckhauser, 1988). Similarly, the diversity of ways in which

[25] If, however, a global cap can be agreed upon in the near future, Europe is likely to benefit from an early-mover advantage (Edenhofer et al., 2009). The benefit of the timely redirecting of investments to low-carbon technologies and infrastructure is projected to exceed the costs of a higher cumulative reduction commitment.

circumstances can change provides a government with plenty of excuses to opportunistically adjust its policy.

Political volatility

The above analyses assumed a benevolent and unitary policymaker whose sole objective is the maximization of a common social welfare function. Under a public choice perspective, however, the individuals that constitute the government change over time and hence so may the preferences that are thereby represented. Various stakeholders with conflicting views and interests seek to influence policies to their own advantage. Incumbents may be inclined to use carbon policy for maximizing votes, for example, by reducing the carbon price in order to spur economic growth before an upcoming election.[26] Further, policy risk arises when shifting majorities in politics lead to alternating represented special interests (Strausz, 2009). Based on different ideologies and constituencies, carbon policy may look very different depending on which political party is in charge.

Another source of political volatility is changing public opinion. Although the equilibrium preference for climate protection may be relatively stable over time, the public's temporary awareness of environmental problems may be subject to issue attention cycles (Downs, 1972). Peaks in problem awareness (e.g. after climate-related disasters) can lead to more stringent carbon policy (Brunner, 2008). By the same token, carbon policy may eventually be weakened when other issues such as unemployment move up the political agenda. Indeed, it seems likely that political volatility is skewed toward the downside (less stringent carbon constraints) rather than the upside because of the asymmetric temporal cost structure of carbon pricing. Whereas abatement costs accrue immediately, benefits largely materialize in the distant future in form of avoided impacts from climate change. Although many people feel morally obliged to abate their adverse effect on posterity, the temporary willingness to sacrifice current income to protect future generations from serious harm may wane under difficult economic conditions.[27]

Carbon policy is hence at risk of being undermined by constant economic pressures that prefer to roll-over the costs of mitigation to posterity. A society interested in providing

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[26] See Drazen (2000) for a review of the empirical evidence of political business cycles in fiscal and monetary policy. It is unclear whether similar patterns can be expected to occur in carbon policy.

[27] If all societal groups had their interests represented, then all external effects would become internalized and the political equilibrium would be socially efficient (Aidt, 1998). However, pressure groups representing the interests of future generations tend to be relatively weak (see Tremmel (2006), who discusses some models of institutionalization). Even in a purely intragenerational context, collective action problems arise. As Olson (1971) argues, economic interest groups tend to voice their preferences more effectively than public interest groups because they usually are well organized, homogenous and able to provide benefits to their exclusive membership.

credible incentives for emissions abatement should want to reduce short-term political volatility. The cost of commitment, however, is that it also increases the obstacle to policy change when collective preferences in regard to climate protection move toward a new equilibrium. Commitment then raises questions of democratic legitimacy as it restrains policymakers' ability to respond efficiently to new preferences. The debate over constitutionalism versus democracy involves similar questions. In a review of the arguments, Holmes (1988) concludes that constitutional rules promote - rather than limit - democratic decision making. As he puts it, a constitution is a limit imposed by 'Peter when sober on Peter when drunk' (p. 196). Lazarus (2009) reviews arguments in the context of climate policy.

Balancing commitment and flexibility

Risk sharing

The dilemma of carbon policy is that society is forced to choose a balance between the different benefits and costs of commitment. Determining the appropriate degree of commitment is beyond the scope of our analysis (for an attempt in the context of utility regulation, see Blackmon and Zeckhauser, 1992). It should be emphasized, however, that regardless of the commitment level governments enshrine in their policies, the ultimate outcome of their decision is the allocation of risk between public and private actors. Under complete flexibility, the risk of policy change is fully borne by the private sector. Firms react by either postponing investment or increasing their required rate of return (which is not necessarily inefficient from a social perspective). Efficiency depends on who is best able to carry the risk in question. Optimal risk allocation requires that actors accept risk in proportion to their ability to bear it (Hepburn, 2006). IEA (2007) maintains that governments are better placed to underwrite some carbon policy risks for a number of reasons. First, the long-term and incalculable scope of climate change (and therefore carbon pricing policy) impede insurability, and private agents might not be able to relocate and diversify policy risk. Moreover, if government faces a political incentive to change policy (e.g. for pleasing voters by lowering carbon, and hence energy, prices), it can reap the benefits without bearing the costs. The costs of policy change will be more carefully taken into account if governments have a share in them.

The current commitment gap

Although risk sharing seems appropriate on efficiency grounds, carbon policy, as currently practiced in most countries lacks credible commitment to long-term objectives. Politicians are quick to sign up to ambitious aspirations in the form of 'reducing emissions of greenhouse gases in aggregate by 80% or more by 2050' (G8, 2009, p.19) but remain reluctant to enshrine necessary incentives in credible policies. The first commitment period of the Kyoto Protocol expires in 2012, with some signatories (e.g. Canada) steering toward explicit non-compliance. What happens after 2012 is still the subject of strenuous climate

negotiations. With regard to domestic policies, the US is contemplating the introduction of long-term emissions caps but prospects remain equally unclear. In Europe, the EU ETS extends until 2020 without specifying legal carbon constraints beyond this.[28] In most countries, long-term reduction commitments only exist in the form of political declarations. Policymakers who are interested in triggering the profound economic transition, deemed necessary to limit global warming, might want to entrench their aspirational targets within more credible structures.

Commitment devices

What can policymakers do to increase investors' confidence in long-term carbon policy? What are appropriate institutions to implement a sensible balance of flexibility and commitment? A survey of the literature on commitment devices was undertaken and three distinct strategies distinguished: legislation, delegation, and securitization. By and large, legislative devices leave more flexibility than securitization. Securitization, on the other hand, offers a robust foundation for commitment but is less suited to respond to new realities. Delegation seems to be able to combine flexibility and commitment to a certain extent. This review, however, is only indicative and the question of how individual devices in the end could work depends on their exact design and the adopting country's institutional environment. Spiller (1996), for instance, examines political institutions in the US and Great Britain with respect to their ability to promote credible commitment in utility regulation. Lazarus (2009) reviews legal commitment strategies for US climate policy.

Legislation

Adjustment rule and governance structure

Given the large uncertainties prevalent in carbon policy, the vehicle for commitment should be an adjustment rule, i.e. a policy which is itself contingent on other factors. Ulph and Ulph (2009) point out that many authors somewhat artificially generate a commitment problem in their analyses by only allowing policymakers to commit to a fixed carbon price (tax rate) or quantity (emissions cap) that is supposed to remain constant. Instead, Jakob and Brunner (2011) demonstrate why policymakers should formulate a rule - rather than a rate - that sets the price or quantity of emissions as conditional on pre-defined parameters (e.g. new insights in climate science or new outcomes of international negotiations), thereby limiting the risk of opportunistic discretion and partly reconciling policy flexibility with commitment. Parameters should be chosen such that regulated entities have no influence over their

[28] EU Directive 2009/29/EC specifies an annual linear reduction factor of 1.74% that applies to the emissions cap beyond 2020. Article 9, however, explicitly states that the reduction factor shall be reviewed without indicating for what reasons, in which direction, or to what extent it may change.

development in order to avoid incentive distortions (Rodrik and Zeckhauser, 1988). For example, including abatement cost as one variable of the adjustment rule carries the risk of distortions if the private sector has influence over the cost itself.

There are two general limitations to built-in responsiveness: First, it is practically impossible to formulate rules that hold under all contingencies, a deficiency well known in contract law. One may therefore allow some freedom to respond to an unforeseen circumstance. Evidently, such force majeure provisions constitute loopholes for opportunistic policy adjustments (Dixit, 1996). Second, even if writing such contracts were possible, the relevant contingencies would need to be observed and assessed before they could be explicitly codified in a rule response. Legislation therefore needs to structure the processes under which adjustment rules are monitored, and (in the case of emergency) triggered. Providing for a governance framework that structures these processes in a transparent and accountable way is thus a key element of credible carbon policy.

Of course, the legal quality of a rule matters for its level of credibility. Commitment by means of constitutional law presents a very high hurdle to policy change as parliaments usually need a qualified majority for constitutional amendments. Statutory law typically requires simple majorities. While there is no case of constitutional carbon constraints, the UK was the first country worldwide to enact a fully comprehensive climate governance framework in statutory law. The UK Climate Change Act of 2008 stipulates 'legally-binding' interim (2020) and long-term (2050) targets for emission reductions (UK CCA, 2008). It also set up a governance structure by defining the duties and powers of government, parliament, and an independent advisory body in monitoring, implementing, and (last but not least) updating targets when learning about changes in the relevant parameters (e.g. international climate politics, scientific insights).

Clarity over long-term carbon constraints is essential. Equally important, however, is breaking up long-term commitments into near-term incentives whose impacts can be timely monitored and evaluated. To this end, the UK CCA introduced a carbon budgeting system in which every single budget covers a period of five years and at least three budgets must be set in advance.[29] Setting budgets not only takes into account the overarching long-term target but also a wide range of near-term factors such as economic and technological development (Hill, 2009). In addition, the UK government intends to break down accountability into departmental levels where each minister is responsible for meeting the sub-budget for their own economic sector (DECC, 2010). The downside of short-term budgets, however, is that they may hinder the intertemporal equalization of marginal cost.

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[29] Budgets cover the entire UK economy, including those sectors covered by the EU Emissions Trading Scheme (EU ETS). Having a ceiling on trading-sector emissions may eventually generate conflicts with EU law where a sectoral limit within the EU ETS cap is not foreseen (Sina et al., 2009). This is one reason why commitment devices should strive to match the governance level of relevant carbon pricing instruments such as the EU ETS.

Efficient budgets require that the government knows what the development of abatement cost is over the entire time horizon.

Enforceability and public scrutiny

It is not obvious what the consequences of self-imposed 'legally-binding' targets are at first sight. After all, every subsequent legislature will have the authority to change laws and subsequent governments will be able to change the degree of enforcement. Legislation, however, raises the discursive hurdle for policy change. Targets can no longer be silently dropped when they become inconvenient. Changing laws entails a visible (and perhaps politically costly) process if constituencies are not convinced of the action's legitimacy.

Governments sometimes choose to ignore legislated commitments instead of changing their legal basis. The ability to internally enforce targets against a non-complying government varies over jurisdictions. For example, consider unbalanced carbon budgets in the UK CCA. In theory, every stakeholder has the right to take the government to court if a carbon budget is not met. In practice, judicial review in this issue area is restricted to procedural misdemeanour, and case law demonstrates that such a challenge is likely to fail (Hill, 2009). While the potential for judicial review is limited in the UK, other legal systems allow a greater role for courts or citizens in ensuring effective enforcement. For example, the US legal system offers more opportunities to sue a non-compliant government. Sina et al. (2009) explore the potential of applying a CCA-like framework in Germany and highlight the power of the Federal Constitutional Court to enforce climate legislation. However judicial procedures may be too time-consuming to be practical and the deviating government may be long out of office before the courts sanction a judgment of non-compliance.

Plausibly, the main motivation for government to avoid non-compliance with the law is public scrutiny. If a governing majority anticipates that the political costs of pursuing a certain course of action will be a loss of public support, then taking this route is less attractive. Hence, carbon policy should be deliberately designed so as to encourage public scrutiny, for example, by earmarking revenues from emissions trading for redistribution purposes. A large share of the proceeds from auctioning emission permits could be recycled back to consumers via annual lump-sum payouts. A congressional draft for climate legislation in the US included provisions on earmarking revenues from auctioning (see Cantwell and Collins, 2010). By mitigating (for the poorest households potentially reversing) its regressive distributional impact (Burtraw et al., 2009), a 'climate dividend' could create long-term political support for carbon pricing. It would restructure the incentives for the ultimate enforcer, namely the electorate, to have the policy implemented over time.

Delegation

The general limitation of using legislation as a commitment strategy is that no rule is carved in stone. No government can enact laws or regulations that successors cannot revoke or

dilute. A credible policy is therefore one that tries to insulate implementation from day-to-day politics. Delegating part of the authority to institutions with a time horizon beyond the current legislative period may be a means to this end. In principle, these institutions may be an advisory or an agency.

Advisory

An advisory, or watchdog, is a government-independent monitoring entity that is delegated the authority to advise and monitor government's performance on a regular basis.[30] The UK CCA institutionalized a regular reporting and monitoring cycle through the government-independent Committee on Climate Change. The Committee advises the UK parliament on carbon budgets and policies and monitors the country's progress along the transition path through annual progress reports. The merit of having an independent watchdog lies in forcing government to publically justify its own actions on a regular basis (Lazarus, 2009). Yet the very existence of an organization does not suffice to increase policy credibility: Germany, for example, has three different government-independent advisory bodies for environmental policy none of which can even closely match the Committee on Climate Change's high public profile in the UK.[31] A legal obligation for government to regularly obtain and respond to the organization's advice, as laid down in the UK CCA, and the choice of figureheads with influence in politics and business is critical to give it an authoritative standing. Time will show whether the UK CCA's political clout suffices to effectively check political opportunism.

Agency

In contrast to an advisory where policy control remains with the government, an agency is an institution that is delegated the authority to implement the policy on government's behalf. Two issues play a key role in the rationale for delegation: reputation and objectives. First, Barro and Gordon (1983) investigate how government reputation could mitigate the problem of time-inconsistency in monetary policy. But the transience of leaders and ruling majorities in politics leads to heavy discounting of the future value of reputation. Independent agencies that are insulated from political cycles have stronger incentives to build up and retain their reputation over longer time horizons (Persson and Tabellini, 1994). Second, in the context of commitment, agents can be most valuable when their objectives are distinct from those of the delegating principal (Schelling, 1956). Political opportunism

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[30] A related concept is that of guardians. Guardians attempt to counter-balance the myopic bias of parliaments by deliberately representing the interests of future generations. For example, Hungary installed a Parliamentary Commissioner for Future Generations who has formal participation and review rights during policy formation. See Tremmel (2006) for a review of different models of intergenerational representation.

[31] The Sachverständigenrat für Umweltfragen (founded in 1971), the Wissenschaftlicher Beirat für Globale Umweltveränderungen (1992), and the Rat für Nachhaltige Entwicklung (2001).

often stems from governments facing multiple and at times conflicting objectives (e.g. low energy prices and climate protection). With delegation, the number of objectives per agency can be reduced. 'Political unbundling' (Brunekreeft and McDaniel, 2005) then eases the pressure to renege on past commitments and may help to increase policy credibility in investors' view.

The literature on the benefits of central bank independence inspired Helm et al. (2003) to transfer this device to carbon policy.[32] Similar to monetary policy where the central bank is assigned to meet an inflation target, a carbon agency or 'carbon central bank' could be delegated the duty and powers to meet a certain temperature or emission target by, for example, setting a carbon tax. If the initial staff has some conviction in the task, the evolving organizational culture and sense of mission will create a barrier to change (Wilson, 1989). The separation of politics and administration enables the government to commit to the original program while the rationale/legal constraints of Weberian bureaucracy insulates agents from efficiency-undermining political pressures (Moe, 1990). The agency retains the flexibility to react to changing circumstances but it does so within clearly defined boundaries as laid down in its mandate. As such, delegation might be able to combine the advantages of credible commitment and flexibility.

Limits to institutional independence

If one argues that independent agents can solve the commitment problem in carbon policy, one needs to show when and why independence is costly to reverse. The central bank model has demonstrated how institutional independence can create credibility for time frames relevant for inflation targeting (Cukierman et al., 1992). If a government wants to regain influence over monetary policy (e.g. by lowering interest rates, for an upcoming election, thereby boosting economic growth), the mere announcement of doing so may raise the level of expected inflation, undermining the political goal of price stability. Before government actually regains control over monetary policy to produce the benefits it seeks, it will pay the costs of its attempt, thereby acting as a deterrent to performing the action in the first place. Time frames in carbon policy, however, are considerably longer than in monetary policy. The inertia in the built energy system might allow governments to abolish carbon agency independence without immediately suffering the costs in the form of significantly higher emission levels.[33] Note that an actual reversal of institutional independence is not even necessary. The mere threat to abolish independence suffices to influence agency decisions (McCubbins and Schwartz, 1984). Moreover, as Helm et al. (2003) point out, the trade-off between economic growth and monetary stability exists only in the

[32] At the international level, Barnes et al. (2008) propose to create an Earth Atmospheric Trust that administers the global carbon budget with the aim to maximize the long-term benefits on behalf, and in the long-term interest, of global society.

[33] We thank Karsten Neuhoff for pointing this out.

short run. Carbon policy, by contrast, must balance the objectives of low energy prices and climate protection over longer time spans. To a certain extent, carbon pricing implies an intergenerational redistribution of welfare where the present generation bears costs (higher energy prices) to the benefit of future generations (lower damage cost from climate change). Delegating carbon policy to an independent agency may therefore face substantial resistance from those groups who argue that the task of resolving intergenerational distributional conflicts should remain within democratic institutions.

Securitization

As mentioned above, constitutions offer a robust foundation for commitment because political hurdles to change constitutional provisions are high. An integral part of most constitutions is the protection of private property. Securitization as a commitment strategy acts as leverage on these provisions by entrenching commitments in private property rights and contracts.

Contracts and carbon pricing

From an economic perspective, the legal characterization of commitment matters insofar as it impacts incentives. The less reliable a commitment is, the lower are market participants' incentives to invest in its implications. In this context, it is worth considering feed-in tariffs for renewable energy sources. A major strength of feed-in tariffs is that they provide a legal guarantee of revenues. Lowering the tariff within the guaranteed period faces high legal hurdles because it undermines contractually agreed payments and directly devalues investors' property.[34] Carbon taxes and emission caps, by contrast, can be adjusted freely without violating any contractual agreements. In fact, the power to introduce and abolish taxes at their own discretion is constitutive of parliamentarian sovereignty, and political constitutions shield rather than confine this power. Moreover, taxes seem less suitable to establish credible commitment because, in contrast to tradable permits, they do not directly create a financial market constituency interested in the continuation of the policy.

The introduction of contracts in carbon pricing therefore rests on the use of quantity-based instruments. The conventional assumption among economists is that tradable emission permits represent property rights. Legal experts, however, maintain that permits only grant a limited authorization rather than a private property right per se (Cole, 1999; Woerdman, 2005). Allowance holders do not own disposal space in the atmosphere. Rather, regulators recognize property rights in allowances and market participants can receive, hold, and

[34] Nevertheless, feed-in tariffs too may involve regulatory risks. In Spain, the government retroactively announced cuts to remuneration for existing wind power plants in order to manage mounting subsidy payments. However, the market participants believe that this cut is unlikely to affect investors' property because it will only come into force when a certain (relatively high) number of operating hours is exceeded (Platts, 2010).

transfer allowances. The value of allowances of course depends on regulation and regulators can modify or terminate trading regulations without necessarily infringing property rights. Hence, the establishment of a tradable permit system where participants hold emission 'rights' does not provide sufficient protection against opportunism.

Enhanced tradable permit systems

Enhanced tradable permit systems build on current allowance markets but add some additional features. One means to strengthen the commitment to trading systems is to prolong the validity of permits (McKibbin and Wilcoxen, 2007). Long-dated permits allow their owners to emit one unit of emissions each year over the lifespan of the permit (e.g. 30 years). Permit owners have an interest in keeping the system running and the cap tight because these increase the scarcity value of their asset. They form a countervailing constituency against political attempts by subsequent governments to dilute commitments. To allow for flexibility, a fixed supply of long-dated permits could be combined with a variable supply of annual permits that can be adjusted in response to new information and preferences. However, long-dated permits may be prone to strategic investment hold-up (Biglaiser et al., 1995) as permit owners with market power might be inclined to strategically under-invest in abatement, thereby driving up permit prices and increasing the market value of their assets.

With put-options on emission allowances, investors could hedge their low-carbon assets against the downside of a carbon price risk while also providing government with a contractual incentive to honour its commitment (Laffont and Tirole, 1996; Kemp and Swierzbinski, 2007; Ismer and Neuhoff, 2009). Put-options may be partly seen as an equivalent to feed-in tariffs in terms of incentive- and risk- structure since they too ensure that part of the costs of learning effects are borne by tax payers. The government, having sold the option, has financial incentive to adhere to set targets and keep permit prices above the committed minimum. If the volume of outstanding options is sufficiently large, a price floor for emission allowances will emerge in the carbon market. As financial contracts, put-options are protected by constitutional provisions and can be enforced against government through independent courts. While they represent a powerful commitment device, regulators can freely choose the overall level of aspired commitment via three parameters: (i) strike price, (ii) the number of options issued, and (iii) the duration of options (Ismer and Neuhoff, 2009). Increasing any of these strengthens the commitment.

Carbon bonds and contracts

Carbon bonds and carbon contracts are both devices that can be implemented as complements to existing cap-and-trade (C&T) systems. First, consider a government that issues a bond whose coupon payment negatively correlates with the market price of allowances in an emissions trading system (Mainelli et al., 2009). Project developers investing in low-carbon technologies could buy this bond in order to hedge against carbon

price risk. The carbon bond would transfer part of the risk to government, which then faces a financial incentive to keep prices in the permit market high. The device leverages on the credibility that governments seek on international bond markets because breaking with this kind of commitment imposes high costs in the form of higher risk premiums for public finance. The degree of commitment can be chosen via pay-off structure, duration, or the aggregate volume of outstanding bonds.

Second, the possibility that governments auction off long-term procurement contracts over the supply of emission reductions is complementary to the institutional choice of C&T (Newbery, 2003; Helm and Hepburn, 2007). Firms bid their prices for a specified quantity of emission reductions, and the government closes a contract with the lowest bidder. Tenders can be made technology-blind. Carbon contracts provide firms with a forward revenue stream with long-term price certainty. The government, by contrast, could resell emission credits into C&T systems such as the EU ETS. However, carbon contracts generate emission reduction credits relative to an assumed baseline (an analogue to credits stemming from the Clean Development Mechanism of the Kyoto Protocol). As such, their use is confined to sectors and installations not covered by C&T systems.

Creating countervailing constituencies

What is the common theme of commitment devices? In our view, the key to understanding credible commitment lies in what Dixit (1996) termed a theory of 'transaction-cost politics' or Spiller (1996), less elegantly, dubbed a 'transactions cost-cum-positive political theory' approach. Commitment devices place political transaction costs in the path of policy change in order to mitigate the risks of opportunism. They create or support long-term countervailing constituencies interested in the continuation of the policy. Partly, this strategy relies on the introduction of additional formal or informal veto players in the political system (Tsebelis, 2000). Political transaction costs can accrue in various forms: bad press, the need to seek cross-partisan consensus, logrolling, losing votes, lower contributions from interest groups, admonition from courts, financial expenditures etc. Political transaction costs do not put an absolute limit on government flexibility. Rather, they provide future majorities with an incentive to adhere to the announced course of action by decreasing the gains from deviation.

However, there are many open questions both in theory and in practice. This review lacks an analytical framework within which the net-benefits and feasibility of individual proposals can be compared. Both factors depend on a country's objectives and institutional endowment and can therefore only be assessed on a case-by-case basis. The development of a political transaction-cost framework for carbon policy and its application to a case-specific institutional context is a task that is left to subsequent work.

Conclusions

There is a fundamental trade-off between flexibility and commitment in carbon policy, and the benefit of commitment decisively depends on the source of regulatory uncertainty. Three sources of carbon policy uncertainty were identified: First, in a deterministic setting, the strategic interaction between government and firms may have adverse effects if policy is flexible. The mere anticipation of time-inconsistent decisions leads to investment-hold up. Ratchet effects occur when firms see a chance of influencing future policy choice by changing their own performance. Commitment to future policy is valuable in this setting. Second, under uncertainty, commitment may lead to socially inefficient outcomes if it impedes government's flexibility to respond to unforeseen developments in science, technology, and international politics. The presence of uncertainty also makes it difficult to distinguish opportunism from reasonable responses to changed circumstances. Third, political volatility in the domestic arena amplifies investment risks but strong commitment (which binds successive majorities) raises questions of democratic legitimacy. In brief, the dilemma of carbon policy is that society is forced to balance the different benefits and costs of commitment. The degree of government commitment determines the allocation of risks between public and private actors. Weak commitment imposes most risks on the private sector. Current carbon policy around the world is largely characterized by relatively weak commitments. Governments interested in triggering the economic transition deemed necessary to mitigate climate change might want to entrench long-term carbon policy in more credible structures.

How can governments attain a higher degree of commitment and credibility? Commitment devices were reviewed that internally restructure the incentives for successive governments to adhere to set policies. The underlying rationale of legislation, delegation, and securitization is to create and support countervailing constituencies with a long-term interest in emissions abatement. First, legislation can provide a transparent governance structure for setting, implementing, and updating carbon policy. A legal duty to write carbon budgets ensures accountability and continued attention to the policy issue. While enforceability cannot be generally guaranteed, earmarking carbon revenues for redistribution to consumers is one way of ensuring public scrutiny over time. Second, delegation insulates interests dedicated to emissions abatement from day-to-day politics while preserving the capacity for flexible adjustments. The institutional mandate may define monitoring and advisory duties. It may also delegate the authority to set policy on government's behalf to an independent carbon agency. Clearly defined agency objectives together with stronger incentives to retain reputation can improve the credibility of delegated policy. Third, securitization protects investors' stakes in carbon markets by entrenching commitment in enforceable contracts. In particular, put-options on emission allowances fit well with the institutional setting of cap-and-trade systems. In sum, these strategies may help to anchor private sector expectations regarding the future profitability of emissions abatement.

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4 Commitment under uncertainty: an adjustment rule for climate policy

[This chapter is submitted for publication as: Jakob, M., & S. Brunner: Commitment under uncertainty – an adjustment rule for climate policy.]

Abstract

This paper analyses the optimal degree of commitment to a future climate policy when damage costs from climate change are uncertain within the framework of a sequential game between firms and a regulator. Our results question the assertion of previous studies that commitment to the optimal ex-ante target can achieve the social optimum, as under uncertainty, there is a trade-off between commitment and flexibility. Credible commitment to a future policy reduces the risk of time inconsistency but imposes costs in the form of reduced flexibility to respond to new information. If, however, the regulator commits to an adjustment rule that sets the abatement level contingent on the realization of the uncertain outcome, the social optimum can be obtained.

Introduction

Taking effective action to avoid dangerous climate change requires credible commitment to long-term climate policy (Helm et al. 2003). A problem, however, arises if the policy is prone to the risk of time inconsistency. The general concept of time inconsistency – elaborated in the context of macroeconomic policy by Kydland and Prescott (1977) – describes a situation in a dynamic game in which the regulator has an *ex-post* incentive to renege on a policy that was optimal *ex-ante* (Petit, 2009). In the context of climate policy, it has been recognized that the development and adoption of innovative low-carbon technologies by the private sector may be impeded by time-inconsistency: in order to provide incentives for firms to undertake irreversible investments in R&D, the regulator has to announce a relatively high future carbon price. Once these investments are undertaken, however, the socially optimal *ex post* carbon price set by the regulator is too low for firms to recoup their investment (Kennedy and Laplante 2000; Requate and Unold 2003; Montgomery and Smith, 2005). As firms anticipate this outcome, the regulator's announcement is not credible and under-investment results.

Previous literature has pointed out that a regulator's optimal policy to deal with time-inconsistency is to credibly commit to its *ex-ante* optimal level (e.g. Biglaiser et al. 1995; Helm et al. 2004). This paper shows that if one acknowledges the presence of uncertainty over the benefits of climate change mitigation, the former contention – derived in a deterministic setting – does not hold anymore. Under uncertainty, it will be desirable for the regulator to have some flexibility to adjust the target to respond to new information. We also demonstrate that if the resolution of uncertainty can be observed *ex-post*, the socially

optimal outcome can be obtained with a state-contingent rule that determines the amount of emissions abatement to be provided as a function of the uncertain variable[35].

This paper proceeds as follows: Section 2 presents a deterministic Stackelberg game in which the social optimum is obtained if the regulator can commit to a certain policy level but time inconsistency emerges if firms move first. We then introduce a term into the regulator's objective function that punishes deviations from announced policies to generalize the polar cases of full commitment and no commitment. Section 3 derives the optimal level of commitment under uncertainty and shows that the social optimum can be achieved with a credible commitment to an adjustment rule. Section 4 discusses commitment devices and implementation options. Section 5 concludes.

A general formulation of time inconsistency and commitment

One example for time inconsistency is when a regulator announces a future climate policy *ex ante* but faces an incentive to change the policy after the regulated entities have taken their investment decisions. Consider a regulator that decides about the aggregate level of emissions abatement *e* (the climate policy) to be provided by firms that can lower their abatement costs by investing in technology *t* at R&D cost $\vartheta(t)$, with $\vartheta_t(t) > 0$.[36] Let $b(e)$ and $c(e,t)$ denote the (social) benefits and (firms') costs of *e*, respectively, with $b_e(e) > 0$, $c_e(e,t) > 0$, and $c_t(e,t) < 0$. Throughout this paper, we assume that all parameters determining the firms' as well as the regulator's decisions are public knowledge[37].

The first-best solution is obtained maximizing the following social welfare function:

$$W = b(e) - c(e,t) - \vartheta(t) \tag{1}$$

---

[35] The literature on credible long-term environmental policy has remained predominantly silent with regard to the trade-off between commitment and flexibility (Brunner et al. 2012). Lyon (1991) investigates under which conditions hindsight review can be superior to ex-ante rate of return regulation. Blackmon and Zeckhauser (1992) examine a regulatory game with uncertainty and show that delegating regulation of utilities to an entity whose preferences are biased in favor of firms' interests also serves consumers by inducing higher investment levels. Boyer and Laffont (1999) show that constraining the choice of instruments available to politicians can limit their undue promotion of the interests of their constituency. However, equipping politicians with discretionary power is the more desirable the greater the variability of relevant economic parameters such as firms' costs, stakeholders' preferences, or the social costs of public funds.

[36] Subscripts denote partial derivatives

[37] There exists a gap in the literature because the problem of time-inconsistency under asymmetric information has hitherto not been analyzed .

Calculating the derivatives yields the following first-order conditions for the optimal values of *e* and *t*:

(i) $b_e(e^{opt}) = c_e(e^{opt}, t^{opt})$, and (2)

(ii) $c_t(e^{opt}, t^{opt}) + \vartheta_t(t^{opt}) = 0$ (3)

Let us consider a three stage game à la Stackelberg. First, the regulator announces its abatement target *e*. Second, firms invest in emission saving technologies. In the final stage of the game, the regulator implements a policy to achieve the socially optimal level of abatement *e*. This formulation captures essential properties of long-term climate policy.

Lemma 1: If the regulator has a device to credibly commit to e, the socially optimal outcome can be obtained.

Proof: In the decentralized solution, firms choose their level of technology *t* to minimize their total costs $c(e,t) + \theta(t)$. If the regulator is able to credibly commit to its choice of *e*, it opts for e^{opt} in the second stage, firms choose technology t^{opt}, and the socially optimal outcome is obtained.

Lemma 2: If the regulator is unable to credibly commit to the announced level of e, the firms choose technology level t which is below the social optimum as compared to the case with credible commitment. The same holds for the regulator's choice of e.

Proof: If the commitment is not credible, firms anticipate the government's reaction when deciding their level of technology. In this case, the regulator's first-order condition in the final and decisive period, taking the firms choice of technology as given, becomes:

$$b_e(e^{reg}) = c_e(e^{reg}, t^f). \quad (4)$$

This condition implicitly defines the regulator's reaction function to firms' choice of technology. It can easily be verified that $\frac{de^{reg}}{dt^{firms}} > 0$, i.e. the regulator responds to firms' choice of a lower level of technology by adopting a less ambitious emissions abatement

target. The firms' technology choice is determined by their cost minimization problem, taking into account the regulator's reaction function:

$$\min_t [c(e,t) + \vartheta(t)] \Rightarrow$$

$$c_e(e^{reg}, t^f)\frac{de^{reg}}{dt^f} + c_t(e^{reg}, t^f) + \vartheta_t(t^f) = 0 \tag{5}$$

As the first term is positive, $c_t(e^{reg}, t^f) + \vartheta_t(t^f) < 0$. This means that the social cost of supplying *e* is not at a minimum, as would be required by the optimality condition $c_t(e,t) + \vartheta_t(t) = 0$, but could be further decreased by increasing *t*. However, given the regulator's reaction function, such an increase in *t* would also raise the total level of emissions abatement *e* that firms are required to provide. □

As firms anticipate that lower marginal costs due to technological innovation will prompt the regulator to adopt more stringent policy, they choose a level of technology below the social optimum. In our model, this 'ratchet effect' (Weitzman, 1980), which is due to the regulator's flexibility to react to firms' choice of *t*, results in a time-inconsistent choice of the abatement target *e*.[38] However, this problem can be overcome if the regulator has a means to credibly commit to its future actions. A commitment is only credible if the cost of breaking it exceeds the potential gains from deviation (Schelling, 1960). The regulator hence only has an incentive to adhere to a prior commitment if deviation results in a punishment that is sufficiently large. If the punishment depends on the magnitude of the deviation from the announced policy, the regulator's optimal *ex-post* policy is determined by its *ex-ante* commitment and the severity of the punishment. If the punishment for an infinitesimally small deviation from the announced policy approaches infinity, the regulator never has an incentive to deviate from the announced policy and perfect commitment is obtained.

<u>Lemma 3</u>: The cases of 'perfect commitment' and 'no commitment' as well as all intermediate cases can be modeled by introducing a punishment function Θ into the regulator's objective function.

---

[38] Note that by modeling one representative firm, we implicitly assume that firms are able to coordinate their actions. If a single firm's action has no influence on the regulator's reaction, the problem of time-inconsistency does not arise in our framework. Thus the formulation chosen here can be expected to be suitable for monopolistic and oligopolistic markets, such as power generation in many countries.

Proof: Let the regulator's objective function be

$$W = b(e) - c(e,t) - \vartheta(t) - \Theta(e - e^{opt}) \text{ with } \Theta' > 0 . \quad (6)$$

Obviously, the case of no commitment is obtained for $\Theta(e) = 0$. Furthermore, it can be easily verified that $\frac{de^{reg}}{dt^{firms}} \to 0$ for $\Theta(e \neq e^{opt}) \to \infty$, which yields the full commitment setup. Between these polar cases lies a continuum of setups in which the regulator is punished for deviations from the pre-announced policy. □

With perfect foresight, it is clear that perfect regulatory commitment is the most desirable option from a social perspective. However, in presence of uncertainties with regard to benefits and costs of emissions abatement, some flexibility to deviate from prior announcements in order to react to unforeseen events can prove advantageous. Therefore, as we show in the next section, there is a trade-off between adopting strong commitment devices to strengthen the time-consistency of a policy versus the flexibility to accommodate new information.

Commitment under uncertainty

We outline a simple analytical model with linear benefits, quadratic abatement costs decreasing linearly in investment in technology *t*, and a quadratic R&D investment cost function to acquire technology level t, characterized by the parameter *k*. We analyze the impacts of additive uncertainty in the slope of the benefit function[39], characterized by its expected value *b* and the realization of a random shock ε. We assume that the magnitude of the regulator's punishment Θ for deviating from an announced target is characterized by the non-negative parameter θ and quadratic in the difference between the announcement e^* and the actually implemented level e'. This formulation of a commitment device can be understood in terms of the reputational costs associated to violating a pledge à la Barro and Gordon (1983), or political costs in terms of renegotiating legislation (Brunner et al., 2012). Monetary costs can be introduced in an emission trading system by means of put options that obligate the regulator to buy back permits at a pre-defined price in the future (Ismer and Neuhoff, 2009). Section 4 discusses such devices to establish credible commitment in more detail.

[39] In climate policy, the largest sources of uncertainty relate to the damage costs of climate change (IPCC, 2007). At the same time, uncertainties regarding mitigation costs and costs of technology development undeniably play important roles, too.

The model is hence fully specified by the following set of equations:

$$
\begin{aligned}
&b(e) = (b+\varepsilon)e'; \;\; E(\varepsilon) = 0; \;\; Var(\varepsilon) = \sigma^2 \\
&c(e) = \frac{1}{2}ce'^2 - te' \\
&\vartheta(t) = \frac{1}{2}kt^2 \\
&\Theta(e', e^*) = \frac{1}{2}\theta(e' - e^*)^2
\end{aligned}
\tag{7}
$$

We require all parameters *b*, *c*, *k* and θ as well as the choice variable *t* to be non-negative. The social welfare function is given by:

$$
W = (b+\varepsilon)e' - \frac{1}{2}ce'^2 + te' - \frac{1}{2}kt^2 - \frac{1}{2}\theta(e' - e^*)^2 \tag{8}
$$

Again, the game proceeds in three stages: In the first stage, the regulator (R) announces the target e^* which it aims to implement in the final stage. In the second stage, the uncertainty regarding benefits is resolved and firms (F) choose their level of technology *t*.[40] In the third stage, the regulator decides on the level of emissions abatement that is actually implemented (e'), given the realization of the new information ε regarding benefits as well as firms' choice of *t*, and firms supply e' at the corresponding cost function (Figure 1).

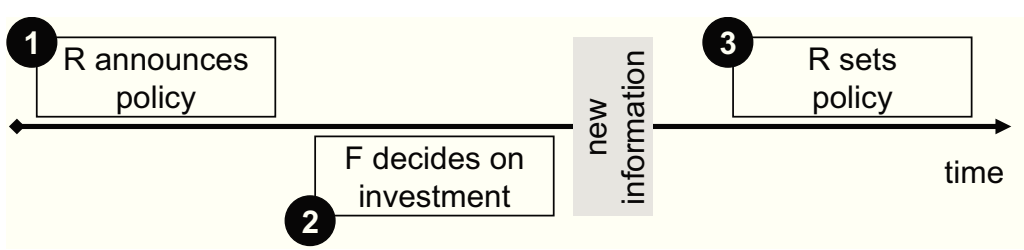

Figure 1: Emissions game between regulator (R) and firm (F) under uncertainty

The decentralized nature of the strategic interaction between the regulator and the regulated firms requires both players to form expectations of future scenarios (which are

[40] Hence, firms do not face uncertainty when deciding on their technology level

determined by the other player's action, and, for the regulator, the possible realization of the shock). To solve the problem, we apply backward induction from the third to the second and finally to the first stage.

The Third Stage

In the third stage, the regulator chooses e', the level of emissions abatement to be performed by the firms, taking as given technology *t*, the realization of the shock ε, as well as e^* (its own announcement of the first stage). Its maximization problem then yields:

$$e' = \arg\max_{e'}[W] = \arg\max_{e'}\left[(b+\varepsilon)e' - \frac{1}{2}ce'^2 + te' - \frac{1}{2}kt^2 - \frac{1}{2}\theta(e' - e^*)^2\right] \Rightarrow$$
$$e' = \frac{(b+\varepsilon)+t+\theta e^*}{c+\theta} \tag{9}$$

The level of emissions abatement that the regulator actually requires firms to supply is the higher (i) the larger actual benefits, i.e. $(b+\varepsilon)$, (ii) the higher the firms' level of technology *t*, (iii) the more ambitious the announced target e^*, and (iv) the lower marginal abatement costs *c*.

The Second Stage

In the second stage, firms take the regulator's announced policy e^* as given from the first stage and anticipate how it will react in the third stage to their second stage choice of *t*. Firms observe the shock ε occurring to the benefit function and decide which level of technology to employ in order minimize their total costs:

$$t' = \arg\min_{t} \frac{1}{2}ce'(\varepsilon,t,e^*)^2 - te'(\varepsilon,t,e^*) + \frac{1}{2}kt^2 \tag{10}$$

As firms are able to solve the regulator's decision problem in the third stage, inserting e' in Eq.(10) results in the following solution for the firms' technology choice *t'*:

$$t' = \frac{\theta(b+\varepsilon)+\theta^2 e^*}{k(c+\theta)^2 - c - 2\theta} \tag{11}$$

For an inner solution (i.e. cost minimum) to exist, let us assume that the condition $k > \frac{c+2\theta}{(c+\theta)^2}$ holds. Then, *t'* increases with (i) actual benefits $(b+\varepsilon)$, (ii) the regulator's announced policy e^*, and (iii) the strength of the regulator's commitment to its announced target (θ), as all parameters cause firms to anticipate that stricter requirements will be put into place by the regulator in stage three.

The First Stage

In order to be able to decide which target e^* to announce before knowing the actual realization of ε, the regulator has to form expectations about social welfare under all possible outcomes. Plugging the expressions for e' and t' into the welfare function and rearranging terms results in:

$$W = \frac{[\theta e^* + b + \varepsilon]^2[(k(c+\theta)-1)^2 - k\theta^2] - \theta[k(c+\theta)^2 - c - 2\theta]^2 e^{*2}}{2[k(c+\theta)^2 - c - 2\theta]^2} \tag{12}$$

Taking expectations then yields:

$$W^e = \frac{[\theta^2 e^{*2} + b^2 + 2b\theta e^* + \sigma^2][(k(c+\theta)-1)^2(c+\theta) - k\theta^2] - \theta[k(c+\theta)^2 - c - 2\theta]^2 e^{*2}}{2[k(c+\theta)^2 - c - 2\theta]^2} \tag{13}$$

Maximizing this expression with respect to e^* gives us the regulator's optimal choice of e^*, which is only a function of parameters:

$$e^* = \frac{b[(k(c+\theta)-1)^2(c+\theta) - k\theta^2]}{[k(c+\theta)^2 - c - 2\theta]^2 - \theta[(k(c+\theta)-1)^2(c+\theta) - k\theta^2]} \tag{14}$$

Welfare

Inserting e^* into the expression for expected welfare and rearranging terms yields:

$$W^e = \frac{b^2[(k(c+\theta)-1)^2(c+\theta)-k\theta^2]}{2[k(c+\theta)^2-c-2\theta]^2-2\theta[(k(c+\theta)-1)^2(c+\theta)-k\theta^2]} + \frac{\sigma^2[(k(c+\theta)-1)^2(c+\theta)-k\theta^2]}{2[k(c+\theta)^2-c-2\theta]^2} \tag{15}$$

<u>Proposition 1</u>: With uncertainty and committing to a pre-announced policy e^*, neither the case of full nor the case of no commitment yields the optimal result. Rather, an intermediate value of θ (i.e. $0<\theta<\infty$) provides a socially optimal mix of commitment and flexibility.

<u>Proof</u>: Calculating the derivative of expected welfare with respect to θ and evaluating the expression at the extreme values $\theta=0$ and $\theta\to\infty$ shows that $\left.\frac{\partial W^e}{\partial\theta}\right|_{\theta=0}>0$ and $\left.\frac{\partial W^e}{\partial\theta}\right|_{\theta\to\infty}<0$. □

Therefore, for the design of a commitment device, a social planner deciding on the regulator's responsibilities would choose the value of θ such that it maximizes expected welfare. It is not possible to derive an analytical expression for the maximum of the above expression for expected welfare. However, one can employ numerical methods[41] to calculate the values of θ that maximize W^e for different sets of parameters. The result of this exercise is shown in Figure 2, which plots the optimal value of θ as a function of b^2/σ^2. This set of graphs[42] suggests that the optimal level of commitment (i) increases as expected benefits *b* increase and uncertainty *σ* decreases, and (ii) decreases with higher marginal abatement costs *c* as well as technology costs *k*. This finding is in line with

[41] We used Matlab's bounded minimization routine fminbnd

[42] Please note that the optimal *ϑ* is always strictly positive

intuition: the optimal level of commitment is the higher the higher the benefits of mitigation relative to costs, and the lower uncertainty over benefits.

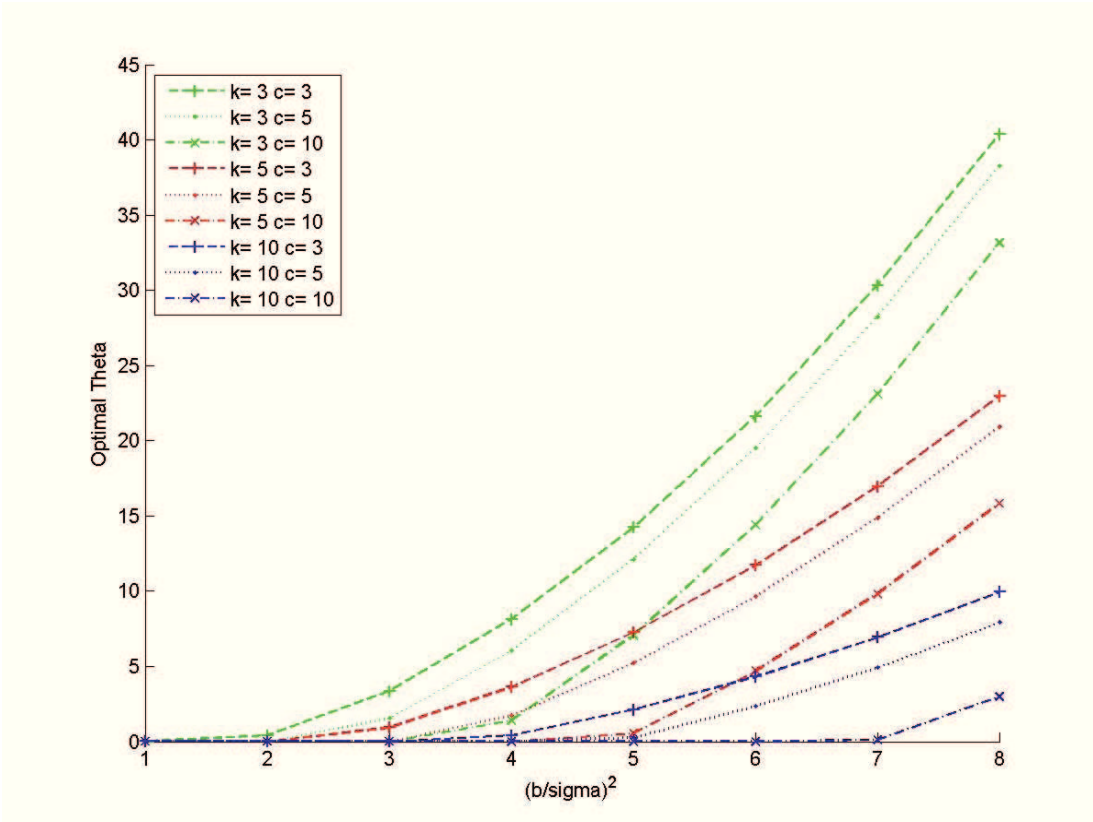

Figure 2: Optimal level of commitment for different values of the parameters k and c

First best solution

Like in the example presented in Section 2, the first best outcome could be obtained by simultaneously choosing *e* and *t* after observing the realization of ε , such that the first-order conditions $b_e(e^{opt}) = c_e(e^{opt}, t^{opt})$ and $c_t(e^{opt}, t^{opt}) + \vartheta_t(t^{opt}) = 0$ are fulfilled. This would result in the following policy:

$$t^{opt} = \frac{b+\varepsilon}{kc-1}$$
$$e^{opt} = \frac{k(b+\varepsilon)}{kc-1} \qquad (16)$$

Plugging these expressions in the social welfare function and taking expectations yields:

$$W^{e,opt} = \frac{(b^2 + \sigma^2)}{2(kc-1)} \tag{17}$$

Proposition 2: With uncertainty, the expected welfare of committing to a pre-announced policy e^* is strictly inferior to the social optimum, regardless of the level of commitment θ.

Proof: Comparing expressions for welfare in the commitment under uncertainty case (Eq.(15)) and the socially optimal case (Eq.(17)) reveals that the two expressions differ, i.e. . $W^e \neq W^{e,opt}$. As the social optimum of Eq.(17) corresponds to the optimal choice of *e'* and *t* (which maximizes expected welfare), Eq.(15) has to lie strictly below and hence cannot be a social optimum. □

Commitment to an adjustment rule

With uncertainty, there is no a-priori commitment to a specific e^* that yields the first-best outcome. However, instead of commitment to a pre-announced policy, the regulator could aim at committing to a state-dependent policy which is enshrined in an adjustment rule that sets e^* contingent on the realization of ε.

Proposition 3: The first-best outcome can be achieved if the regulator has the ability to credibly commit to an adjustment rule which implements a certain level of e contingent on the realization of the shock ε.

Proof: As we have shown in Eq.(16), the first-best outcome implies $e^{opt} = \frac{k(b+\varepsilon)}{kc-1}$ and $t^{opt} = \frac{b+\varepsilon}{kc-1}$. By announcing the policy $e^* = \frac{kb}{kc-1}$ and perfectly committing to an adjustment rule that includes a punishment term of the form $\Theta(e' - e^*) = \frac{\theta}{2}(e' - e^* - \frac{k\varepsilon}{kc-1})^2; \theta \to \infty$, the regulator can implement the socially optimal level of e' even under uncertainty. This commitment strategy deprives firms of their incentive to implement a lower level of technology in order to influence the regulator's

choice of e'. As can easily be verified, their cost-minimization problem results in choosing the socially optimal level of technology t^{opt}.

Hence, perfect commitment to a rule that adjusts the regulator's policy is both time-consistent and optimal[43]. Practical implementation of such policy crucially rests on the assumption that the regulator is able to observe the shock. This seems intuitive for the case of climate change impacts, which commonly are public knowledge. By contrast, if uncertainty would pertain with regard to marginal abatement costs or R&D costs of new technologies - the case not investigated here – significant information asymmetries between firms and government are likely to inhibit adoption of an optimal adjustment rule. Furthermore, from a practical perspective, the implementation of an adjustment rule could face challenges as it would shift the risk of changing information on climate change damage costs to the private sector who may not be in a position to efficiently bear such systemic risks.

Commitment devices

The analytical model introduced a punishment term that incurs costs on the government if it decides to deviate from the committed policy. This punishment term can be implemented by using commitment devices that help to entrench the abatement target and the adjustment rule in credible structures by introducing costs to policy change [44]. Costs can accrue in various forms: time, bad press, the need to seek cross-partisan consensus, logrolling, losing votes, admonition from courts, financial expenditures etc. Devices that incur such costs do not put an absolute limit on government flexibility. Rather, they provide governments with an incentive to adhere to the announced policy by decreasing the gains from deviation. Brunner et al. (2012) identify two groups of commitment devices appropriate to implement an adjustment rule: legislation and delegation.

First, legislation provides the legal foundation for the abatement target, the adjustment rule and a transparent governance structure for implementing and updating the policy. Commitment by means of constitutional law presents a high hurdle to policy change because constitutional amendments often require qualified majorities. Instead of changing

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[43] Note that Ulph and Ulph (2011) show that "what a government should commit to is a tax policy, not a tax rate, and this policy will involve reducing the emission tax if the firm successfully innovates" (p.3). By contrast the rule specified here is not to disincentivize firms' strategic gaming by punishing under-investment, but to provide the regulator with flexibility to respond to the realization of an unforeseen event by re-adjusting his ex-ante optimal target accordingly.

[44] Interestingly, empirical evidence suggests that central banks follow adjustment rules, too, instead of focusing on inflation or interest rate targets (Clarida et al., 2000; Bernanke and Mihov, 1998). See Whitesell (2011) for a discussion of parallels between climate policy and monetary regulation.

legal provisions, the incumbent could also decide to ignore them. Plausibly, the main motivation for government to avoid non-compliance with the law is public scrutiny. If a governing majority anticipates that the political costs of pursuing a certain course of action will be a loss of public support, then taking this route is less attractive. Hence, climate laws could be designed so as to encourage public scrutiny, for example, by earmarking revenues from emissions trading to be recycled back to consumers via annual lump-sum payouts. Such a 'climate dividend' payout system would create long-term public support for climate laws.

Second, delegating authority to institutions with a time horizon beyond the current legislative period may help to insulate interests dedicated to emissions abatement from day-to-day politics. The climate law may foresee the establishment of an independent institution that monitors and advises the government on climate policy. The merit of having an independent watchdog lies in forcing government to publically justify its own actions on a regular basis (Lazarus, 2009). The law may also delegate the authority to set policy on government's behalf to an independent carbon agency (Helm et al., 2003). Independent agencies which are insulated from political cycles have stronger incentives to build up and retain reputation over longer time horizons than their political principals (Barro and Gordon, 1983). Using legislation and delegation in combination may therefore allow the government to credibly commit to a future climate policy by (i) legally enshrining abatement target and adjustment rule and (ii) delegating their implementation to an independent carbon agency. The agency retains the flexibility to react to new developments but it does so within the bounds of the adjustment rule. However, delegation may be opposed by all those who think that climate policies should remain within democratically accountable institutions. In addition, electoral competition could provide an incentive for a political party to avoid delegating responsibility for environmental policy in order to remain relevant for voters.

First attempts to implement adjustment rules and commitment devices for climate policy emerged in Europe. In the UK, a statutory climate law legislates long-term abatement targets and delegates monitoring duties to a government independent advisory body. Adjustments to abatement targets follow a formal procedure where the advisory body observes developments in the economy, climate science, and international negotiations, and eventually recommends the parliament to adjust abatement targets. Somewhat less transparent adjustment procedures exist at EU level. From 2013 onwards, the emissions cap in the European Union Emissions Trading Scheme (EU ETS) will follow a linear reduction trajectory of -1.74% annually. Directive 2009/29/EC specifies that the reduction factor shall be reviewed and perhaps adjusted after 2020, leaving thereby open for what reasons, in which direction, and to what extent it may change. Moreover, the abatement target may be tightened before 2020 if, amongst others, "*more advanced developing countries*" contribute "*adequately"* to global abatement efforts (Art. 28; Directive 2009/29/EC). Vaguely formulated adjustment rules as these may be necessary to capture the multitude of potential outcomes but they may also offer loopholes for opportunistic policy change (Dixit,

1996). Hence, there is scope to improve institutional design by making adjustment rules more explicit and governance structures more transparent.

Conclusions

This paper examines how uncertain climate damages impact on the optimal commitment strategy of a regulator to implement an emissions abatement target. With uncertainty taken into account, it is shown that the common remedy to time inconsistency, namely to credibly commit to an ex-ante optimal target (e.g. Biglaiser et al. 1995) is no longer optimal. Under uncertainty, intermediate levels of commitment which offer a balance between commitment and flexibility maximize expected welfare. We demonstrate that if the resolution of uncertainty can be observed *ex-post*, the regulator can achieve the first-best outcome by committing to a state-contingent rule that adjusts the target level depending of the actual realization of the random variable.

Credible commitment to an adjustment-rule can be established by means of legislation or delegation. Legislation of transparent and accountable procedures is particularly important because of the difficulty to impartially observe key parameters of the adjustment rule such as climate damages or the outcomes of international negotiations.

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5 The neglected side of global mitigation costs

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Abstract

This paper uses insights from New Institutional Economics to explicate the origins and types of transaction costs of international climate finance. Transaction costs rise with the level of contracting uncertainties and include the costs of negotiating, implementing, and monitoring transfers as well as any concomitant inefficiencies that arise from the choice of governance structures. Direct transfers of climate finance are often risky due to weak recipient capacities and the infeasibility of contract enforcement at the international level. Donors respond to uncertainty by delegating the provision of climate finance actions to bilateral and multilateral organizations that implement projects in recipient countries. These direct interventions generate a series of transaction costs. Among donors, harmonization of transfers is hampered by the multiplicity of political objectives, resulting in fragmentation of funds and proliferation of organizations. Long delegation chains between ultimate donor and targeted beneficiary trigger a cascade of principal-agent problems, and donor-driven interventions put an additional burden on anyway weak recipient institutions. The net-benefit of pushing climate finance through the international aid system needs to be weighed against the opportunity cost of this strategy. The potential for such scrutiny is however limited by a broken feedback loop between donor and recipient constituencies. If the extent to which transaction costs accrue and the reason they do so are both known, policymakers might be able to address them more effectively.

Introduction

If an economist were to think of the worst possible transaction setting it would be the following: governments with strong preference heterogeneity employ multiple layers of public bureaucracies to pursue a long-term and difficult to observe outcome in far-away countries where governments have more immediate political priorities and poor institutional capacities and where intended beneficiaries cannot provide effective feedback on the outcome delivered. Such is the setting of international climate finance.

The economic (as opposed to the moral or political) rationale to transfer finance for climate change mitigation from developed to developing countries is based on the assumption that emissions abatement in developing countries can be realized at a lower average cost than in developed countries. Market-based instruments including the Kyoto Protocol's Clean Development Mechanism (CDM) were designed to make use of this cost differential, and the scenarios reviewed by the Intergovernmental Panel on Climate Change (IPCC, 2007) suggest that global mitigation costs can be minimized only if the majority of abatement efforts (in terms of emissions avoided rather than reduced) are realized in developing countries. Yet

one neglected variable in the economic argument for international climate finance concerns the cost of transacting between states. Economic assessments of global mitigation costs usually assume perfect markets that operate with zero transaction costs – one in which one dollar committed by developed countries is assumed to equal one dollar received and spent on mitigation actions in developing countries. Climate finance effectiveness, - that is, the conversion factor of money into desired outcomes - is set to 100%. However, if transaction costs exist and if their extent varies between institutional settings, taking these costs into account when preparing economic assessments could potentially lead to better policy recommendations. Such a consideration would likely provide policymakers with information on the real costs of their actions. If the extent to which transaction costs accrue and the reason they do so are both known, policymakers might be able to address them more effectively.

In order to shed some light on the origin and forms of transaction costs in international climate finance, the next section first introduces basic concepts of New Institutional Economics, a school of thought that focuses on the efficiency of institutions. The subsequent two sections then review the drivers and incidences of transaction costs in international climate finance. Finally, the paper concludes with a brief outlook on on-going attempts to address transaction costs and the role of economic assessments therein.

Climate finance as contracting problem

New Institutional Economics is a perspective that focuses on institutions and the costs of establishing and using them (Williamson, 2000). These costs are often termed ‘transaction cost’ or ‘institutional cost’ and play an important role in environmental policy (Krutilla and Krause, 2010; Coggan et al., 2010). Their conceptual nature is best understood in contrast to the costs examined by conventional assessments of climate policy. Conventional assessments assume a ‘perfect world’ with perfect markets and zero transaction costs. They are primarily concerned with production costs by focusing on supply and demand, on allocative choices over production factors, technologies, and prices. One prominent type of assessment tool used in climate policy is the social planner model that is based on a detailed representation of an energy system including its technology and resource endowments (e.g. Edenhofer et al., 2009). The social planner (an assumed omniscient, omnipotent, and benevolent dictator) thereby optimizes a set of production functions that directly transform decisions into actions and inputs into outputs. Akin to Robinson Crusoe on his seemingly deserted island, the social planner is the sole entity that makes choices in the 'economy'. Williamson (2005) calls this neoclassical perspective the 'lens of choice' and contrasts it with the new institutional 'lens of contract' (Table 1). He argues that while the neoclassical view of hierarchies (the firm, the state) as production functions is well suited to capture production cost, it does so at the expense of losing sight of transaction cost.

	Neoclassical view *lens of choice*	**New institutional view** *lens of contract*
Focus	production cost technology	transaction cost institution
Assumption	perfect institutions/ information	imperfect institutions/ information

Table 1: Neoclassical versus New Institutional Economics.

Consider again Robinson Crusoe whose economy changes in a fundamental way when Friday comes along (Steven Cheung cited in Allen, 2000): the division of labour (as well as information, land, and capital) now gives rise to costs of coordination and cooperation, of creating and using institutions, of establishing and maintaining property rights among individuals and groups of individuals. In short, it gives rise to transaction costs. They are to the social world what friction is to the physical world and institutions are 'social technologies' to address friction. They are the formal and informal rules that guide human behaviour. As North (1990) noted, if a group of people adheres to the same set of institutions, an organization emerges. Some organizations nest in others so that the rules of the higher-tier organization (the state) form the institutional background for the lower-tier organization (the firm). International climate finance as a global cooperative effort relies on a vast number of individuals and nested organizational relationships all over the world. Looking through the 'lens of contract' can hence be useful if one wants to understand at what costs atmospheric stabilization can be achieved and how these costs can be addressed. After all, cost minimization is a matter not only of technological availability but also of institutional availability.

Assessments of the transaction costs of international climate finance are largely absent from the economic literature, although there exists a wealth of theoretical material. As Ronald Coase (1937) famously argued, such costs can be high enough to affect the choice of what and with whom to transact. They can even outweigh the benefit of transacting such that unilateral action may be the best course of action from an economic point of view. Ironically, ignorance toward transaction costs remains both because and in spite of Coase's work: *"the world of zero transaction costs has often been described as a Coasian world. Nothing could be further from the truth. It is the world of modern economic theory, one which I was hoping to persuade economists to leave"*, (Coase, 1992: 716). Modern economic theory assumes a world of zero transaction costs because it takes the Coase theorem, a thought experiment to demonstrate the significance of transaction costs, at face value. The theorem states the separability of allocation and efficiency. According to the theorem, economic exchange will lead to an efficient outcome regardless of the initial allocation of property rights if and only if i) all institutions including property rights are complete, ii) information is complete, and iii) transaction costs are zero. In other words, regardless of who gets what and how much, the market will ensure that resources end up where they can be put to efficient use.

The truth is that transaction costs are positive in all markets, including relatively well functioning capital markets in developed countries. In political markets, they tend to be pervasive (Dixit, 1996; Acemoglu, 2003) especially in political cross-border transactions. As Keohane (1985) notes, transaction costs are very high in international relations because contracts cannot be enforced, giving rise to severe contracting uncertainties. Inverting the Coasian conditions hence delivers a more accurate picture of state-to-state transfers such as international climate finance.

Drivers of transaction costs in international climate finance

Incomplete institutions

The first driver of transaction costs lies in the incomplete set of property rights that flow through the international climate finance system. The Coase theorem requires property rights to be complete, which in turn necessitates that institutions for their enforcement are complete. If climate finance contracts established an enforceable claim toward receiving a certain payment for a certain purpose over a certain period of time, this situation could be termed as one in which property rights are complete and contractual uncertainties low. The German feed-in law for renewable electricity provides an example of well-defined property rights in national climate finance. By complying with the conditions specified by the law, investors acquire a legally enforceable claim to receive a technology specific tariff payment over 20 years. The high credibility of this institution is one reason for the effectiveness of feed-in tariffs in encouraging investments in renewable energy projects (Brunner et al., 2012).

No such credible institution exists for international climate finance. It doesn't exist, first of all, because the international system is essentially anarchic (Waltz, 1979) and legal entitlements cannot be enforced against non-complying states. Moreover, relevant legal provisions remain vague on many essential aspects:

- What qualifies as international climate finance? There is no agreed definition on the funding purposes that are eligible, except for the broad measures described under Article 4.1 in the Convention (UNFCCC, 1992). Moreover, Art. 4.3 requires that the "agreed full incremental costs" of implementing adaptation and mitigation measures shall be covered by developed countries. How to establish the baseline for calculating the increment is still an open question 20 years after the Convention entered into force.

- How much, when and for how long? Long-term climate finance shall be in the range of a "balanced" share of the USD 100 billion per year and "new and additional" to Official Development Assistance (UNFCCC, 2011). Given the lack of a definition of these terms, each country will make its own judgment of balanced allocation and

additionality of funds. Moreover, there are no mid-term financial targets and the long-term finance period has a starting point (2020) but no end point. Consequently, the availability of finance is unpredictable.

- Who is delivering how much finance to whom? The Copenhagen Accord (UNFCCC, 2010) establishes a collective responsibility ("mobilizing jointly") for the provision of finance without attributing shares to donors. On the recipient side there is even more uncertainty about the future finance allocation each country can expect because there is no agreed international allocation key. Moreover, since Durban (UNFCCC, 2012a) it is unclear which countries will be eligible recipients, as Parties decided to abolish the grouping into developed (donor, Annex 1) and developing (recipient, Non-Annex 1) countries.

Conflict over the definition and interpretation of essential legal provisions is so stark that property rights and institutions in international climate finance are likely to remain incomplete. A similar perspective holds for the incompleteness of information that flows through the system and which is another key driver of transaction costs. Both drivers are interdependent because a complete set of institutions could greatly enhance the set of available information through enforceable monitoring, reporting, and verification provisions.

Incomplete information

The second Coasian condition requires information to be complete, including information on the attributes of the transaction item and the objectives of the counterparty. International climate finance, however, operates in a context that is determined by deep uncertainties. Climate finance can be targeted at mitigation or adaptation or both. Each of the objectives can be pursued through various transaction items including money, knowledge, and equipment. Moreover, parties to a climate finance transfer tend to pursue objectives that are not conferred to a narrow mitigation/adaptation benefit. Unlike firms, political actors do not pursue the single observable objective of profit-maximization but rather multiple, often vaguely defined, political objectives (power, profit, prestige, etc.). The multiplicity of objectives is likely to result in the delegation of inconsistent or contradicting tasks and inefficient resource allocation (Martens et al., 2002). Principal-agent theory predicts that in such settings high-powered performance incentives would not only be hard to define but also dysfunctional (Tirole, 1994). They would encourage agents to neglect secondary objectives, thereby disrupting the political consensus among transacting parties. As Easterly (2006) argues aid agents are therefore given incentives to focus their efforts on visible and easy to measure inputs that *seem* to satisfy all objectives at once.

International development cooperation has therefore established a long tradition of focusing on inputs, on 'pushing money', rather than achieving outputs. International climate finance seems to follows this path: the Copenhagen Accord (UNFCCC, 2010) defines an input (USD 100 billion p.a.) but no output (e.g. 100 Giga watt of installed renewable energy

capacity) or outcome (e.g. 100 million tons of avoided CO2 emissions). Measuring inputs is easier than measuring outcomes. It also is less contentious because some donors might want to focus on directly measurable CO_2 reductions while others prefer activities, such as capacity building, that are supposed to foster abatement indirectly. The data on EU Fast Start Finance demonstrate the variety of activities from policy dialogues, to education and renewable energy generation (EU, 2012). Moreover, international mitigation finance is linked to development cooperation and hence strives to meet mitigation co-benefits including employment, poverty eradication or financial sector development. Reflecting these multiple objectives, the OECD DAC allows assigning more than one principle objective, in the form of so called policy markers, per project such as gender equality, trade development or good governance, etc. (OECD, 2007b).

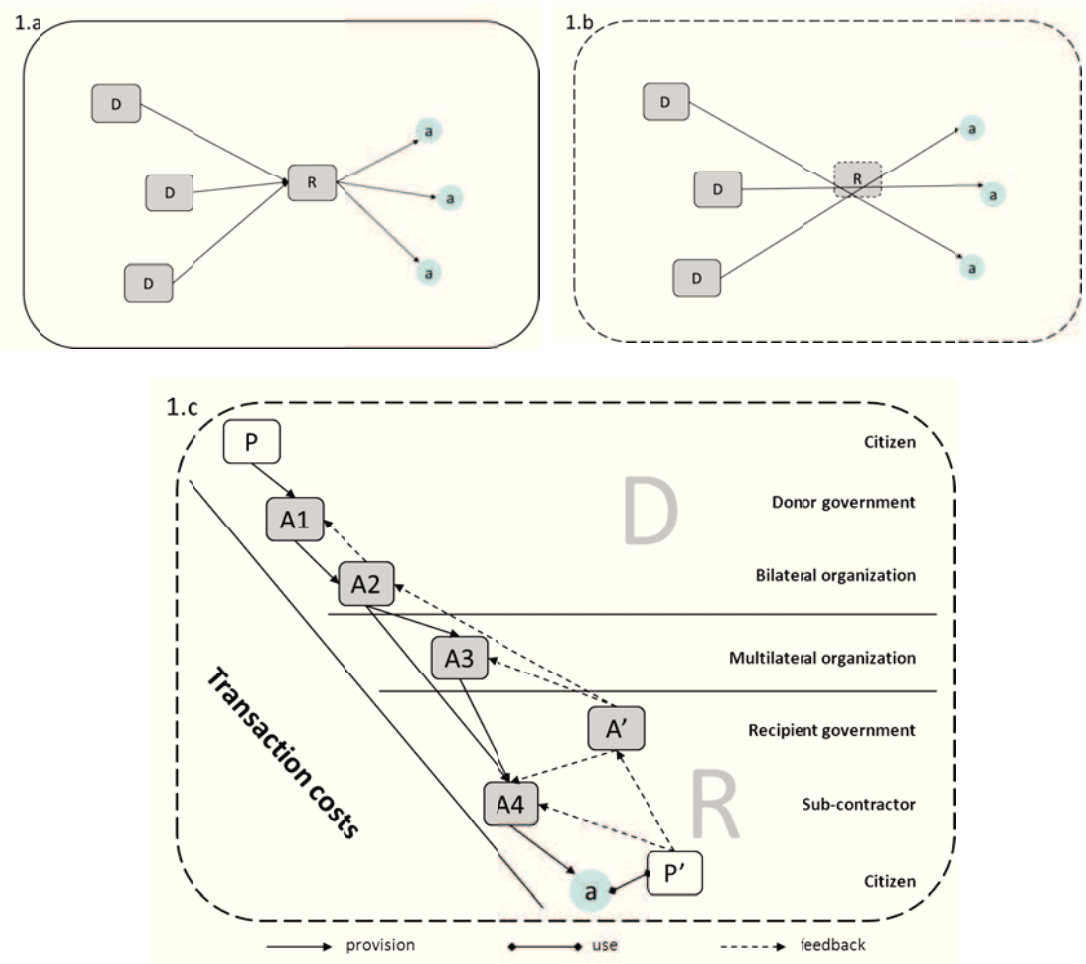
Over and above its incompleteness, information is also unevenly distributed between transacting parties. Asymmetric information gives rise to the hazard of opportunism when a party to a contract uses its private information advantage to the detriment of the counterparty (Williamson, 2000). There are two forms of opportunism: before contract closure, adverse selection denotes a situation when private information enables a party to propose a deal to the detriment of the counterparty. After contract closure, moral hazard occurs when private information during the implementation of the contract encourages hidden defection from agreed terms. Information asymmetries can be observed on the input side and the output side, between donors and recipient as well as among donors.

Moreover, there is a lack of transparency on financial inputs for mitigation finance. The existing reporting systems are incomplete and not used consistently by all financiers. Climate finance flows through a system that makes it extremely difficult to look into numbers, track whether commitments have been met and compare donors' efforts (Tirpark et al., 2010; Varma et al., 2011). It can be assumed that it is not in the self-interest of donors to make their financial support comparable and open their books because that could expose their poor performance. Michaelowa and Michaelowa (2011) found that reporting of climate finance is driven by a political agenda. This potential hidden agenda creates an unhealthy mistrust in the international negotiation and the asymmetric information makes international financial pledges less credible and reliable (Stadelmann et al., 2011).

The problem of incomplete information is acknowledged by the international community and awareness increased during the debate on fast start finance (Enting and Harmeling, 2011). Hence, discussions and negotiations on means to improve the MRV for mid- and long-term finance are in progress. In the context of Nationally Appropriate Mitigation Action MRV for action is assumed to be one core element (Lütken et al., 2012). A growing attention to and momentum for results-based mitigation finance can also be observed (Ghosh et al., 2012). The Green Climate Fund, for instance, is supposed to use performance-based payments where possible and establish a result measurement framework (UNFCCC, 2012b). These initiatives may allow transacting parties to foster transparency, thereby reducing one important driver of transaction costs in international climate finance.

Incidence of transaction costs in international climate finance

Many types of transaction costs in international climate finance are difficult to observe. The most visible type probably is the kind of bureaucratic structure which donors use to provide climate finance. Figure 1 below illustrates how incomplete institutions and information pressure donors to replace (a) direct transfers to recipients with (b) multilateral/bilateral interventions in recipient countries. Part (c) of Figure 1 zooms into the principal-agent chain that results from donor interventions in recipient countries.



1.a: Complete institutions at international and recipient (R) level allow donors (D) to provide support action through direct budget contributions to recipient government who pools and disperses funds on domestic actions (a).	1.b: Incomplete institutions at international and recipient level (dashed lines) create uncertainty that donors reduce by providing support through bilateral/multilateral donor organizations and actions.	1.c: Delegation of actions from donor (P) and recipient (P') principals to donor (A) and recipient (A') agents generates transaction costs at multiple levels.

Direct transfers

If the objectives of both donor and recipient were fully aligned and the receiving party possessed the institutional capacity to use donor support in accordance with shared objectives, the efficient way to deliver climate finance would be a direct contribution to the budget of the recipient government. The recipient would pool donor funds and disperse them on domestic mitigation actions (Figure 1.a). Alignment with recipient institutions, i.e. use of partner systems, would benefit from the fact that local governments usually have both the best information and incentives to satisfy their citizens' needs. However, direct transfers are an exception rather than the rule. Bilateral finance institutions report USD 1.1 billion for mitigation-based policy loans in 2010 compared to an overall USD 15.7 billion of mitigation finance (UNEP, 2011). The EU does not provide explicit information on budget support in its FSF portfolio, but project descriptions suggest very few cases. Contributions to the Kyoto Protocols Adaptation Fund (AF), which amounted to less than 3% in 2010, can serve as a proxy for recipient administered projects (EU, 2012).[45] However, so far less than 20% of the approved funding is channelled through national implementing entities, i.e. the direct access modality (Adaptation Fund, 2012).

With incomplete institutions and information, donors have an incentive to replace direct transfers with direct interventions in recipient countries (Figure 1.b). Donors thereby try to avoid *unrealized* transaction costs (e.g. opportunism) by delegating actions to their own agencies over which they have better information and control (Martens, 2005). They thereby realize a different set of transaction costs that Green (2004) groups into two main forms that are relatively easy to track: the increasing proliferation of funding organizations and fragmentation of funds in international climate finance. Below we discuss these two developments and the concomitant transaction costs they levy on different actors along the delegation chain displayed in Figure 1.c.

Proliferation and fragmentation

The creation of organizational structures that work in parallel to recipient country institutions incurs several concomitant costs. First, it increases the cost of administering climate finance including the cost for staff and office premises. To reduce administrative costs, donors should consider pooling their resources into as few organizations as possible. Yet in order to ensure maximal control over interventions, most donors prefer to run their own bilateral organization. In 2009/ 2010 the majority of financial flows was delivered by bilateral institutions, USD 24 billion compared to USD 15 billion by multilateral institutions (Buchner et al., 2011). Unsurprisingly, proliferation does not only exist for bilateral

[45] It is worth noting that the EU Commission (2011, p.15) supports both mechanisms because "direct access by the beneficiary countries and implementation through budget support can [...] increase aid effectiveness" but seems unable to implement an adequate policy at EU scale.

organization, but is complemented by a variety of multilateral implementing entities and climate funds. Since 2007, 19 major multilateral climate funds became operational.[46] UNDP and World Bank (2012) provide information on 45 multilateral funding sources available for climate action. The average fee international implementing agencies charge for their services consist of 7-9% of the transferred sum, with UN agencies such as UNDP and UNEP ranging at the higher end (Easterly and Pfütze, 2010). If the current donor organization were to manage an additional USD 100 billion of climate finance, Ciplet et al. (2010) expect that up to 40.000 civil servants would need to be hired. Executing part of the task ranging from financial administration to technical evaluation and project implementation in recipient countries eases administration costs.

Second, and paradoxically, climate finance can hamper the development of institutional capacities within recipient countries, a problem that is familiar from ODA (Williamson and Dom, 2010; OECD, 2007a). Donor-driven delivery of many small projects through many different organizations increases the administrative burden on recipients and jeopardizes the ties between the state and its citizens within developing countries. Recipient country bureaucrats focus on the access of climate finance flows. The time they spend on showing donor country delegations around cannot be spend on dealing with citizen demands. (Djankov et al., 2008). For instance, EU fast-start finance donors spread their total contribution of € 2.2 billion in 2010 over 150 implementing agencies and 316 individual 'actions' (EU Council, 2010). The EU Commission (2011: 17) laments that the “large majority of bilateral actions are rather small, pointing to possible efficiency losses due to fragmentation”. These “efficiency losses” refer to excessive administrational cost discussed above. In addition to that, direct interventions add a tragedy of the commons problem in that different donors treat the time of the recipient as a public good without taking into account congestion externalities (Easterly, 2006). Donors first increase the administrative burden on recipients through fragmented direct interventions and then try to mitigate the problem by funding capacity building projects.

Finally, to understand the effect of proliferation and fragmentation on the incentives of all actors in the process, it is useful to frame it as principal-agent problem (Figure 1c). In this model, there exist two principals: donor citizens (P) who elect and fund their government, and recipient citizens (P’) who are supposed to benefit from (at least the private good component) the climate finance intervention. Between the two spans a cascade of principal-agent relationships including bilateral and multilateral agencies, as well as executing agencies on recipient side. The special feature of agency costs in international development transactions such as climate finance is the lack of a closed feedback loop between delegating and benefiting principle (Martens, 2005). Within states, public agents redistribute income between people living in the same political constituency. In development

[46] For a continuously updated list of international climate funds see www.climatefundsupdate.com.

cooperation, in contrast, beneficiaries live abroad and have little means to provide feedback into the donor's political process. Even if they could, they are without means to force donors to react upon their feedback (they might even have an incentive to suppress negative feedback out of fear that donors respond by reducing future aid flows). As a result, climate finance agents on both donor and recipient side operate in an institutional vacuum between donor and recipient principles, an institutional setting that provides very weak incentives to put finance to efficient use. Transparency International (2011) provides a comprehensive account of the corruption risks that can arise in climate finance.

Conclusions

The total economic costs of mitigating climate change through actions in developing countries depends not only on the costs of technologies but also on the quality of institutions that will be available for managing transfers and implementing actions. Transaction costs rise with the level of uncertainty among transacting parties and include the costs of negotiating, implementing, and monitoring transfers as well as any concomitant inefficiencies that arise from the choice of governance structures. Direct transfers to recipient institutions are risky because of weak institutional capacities and the infeasibility of contract enforcement at the international level. Donor governments respond to contracting risks by replacing direct transfers with direct interventions in recipient countries. Among donors, harmonization of transfers is hampered by the multiplicity of political objectives, resulting in fragmentation of projects and proliferation of organizations. The delivery of climate finance through many small projects from many different donors further burdens the institutional capacity of recipient countries. A broken feedback loop between donor and recipient constituencies provides agents in the process with weak incentives to use climate finance in the most effective way.

Without significant institutional innovation, transaction costs therefore have the potential to severely undermine the effectiveness of mitigation finance. The marginal abatement benefit of each dollar transferred turns out to be lower than currently assumed in conventional assessments of global mitigation costs. The net-benefit of pushing climate finance through the international aid system should therefore be weighed against the opportunity costs of this strategy. The acknowledgment of transaction costs will result in a different allocation of international climate finance than that which economic models suggest. It might even become efficient to redirect investment for emissions abatement to developed countries where institutions are more reliable and contracting uncertainties less pervasive.

The good news is that transaction costs can be addressed if there is enough political will for institutional innovation. Room for improvement can be expected in particular in the clarity and measurability of climate finance objectives, as well as in the monitoring, reporting, and verification procedures. The emerging climate finance architecture could be made to profit from the hard-earned lessons of development cooperation. But attempts to craft new

institutions that keep transaction costs in check put considerable strain on UNFCCC negotiations as they involve the transfer of state sovereignty. Economic assessments that provide policy-makers with information on the costs of inefficient institutions could perhaps help to generate the political will that is necessary to improve institutions.

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6 Conclusions

Transaction costs are a measure of what Williamson calls institutional efficiency. I argued above that the key institution in climate policy is the state. As such, the first part of this Conclusions chapter sketches the state's efficiency-boundary by synthesizing insights from the individual chapters along the main research questions. In the final part of this Conclusions chapter, I take a step back to look onto the science-policy interface and my role therein as I perceived it while writing the thesis.

The efficiency-boundary of the state

How can a state address regulatory uncertainty in national carbon pricing when there is no external enforcement mechanism?

Chapter 2 discusses design elements of domestic cap-and-trade systems for greenhouse gas emissions and evaluates their impact on regulatory uncertainty. One important form of uncertainty is the lack of a credible commitment to a long-term trajectory of the emissions cap. Chapter 3 explores means that would allow a state to bind its future self to a certain carbon policy. However, a fundamental trade-off exists between flexibility and commitment and the benefit of commitment decisively depends on the exact source of regulatory uncertainty.

First, in a neoclassical (deterministic) setting, the strategic interaction between government and firms may have adverse effects if policy is flexible. Commitment to future policy is valuable in this setting. Second, under bounded rationality and uncertainty, commitment may lead to socially inefficient outcomes if it impedes government's flexibility to respond to unforeseen developments in science, technology, and international politics. The presence of uncertainty also makes it difficult to distinguish opportunism from reasonable responses to changed circumstances. Third, political volatility in the domestic arena amplifies investment risks but strong commitment raises questions of democratic legitimacy because its binds democratic majorities over time.

A range of commitment devices could help the state to internally restructure the incentives for successive governments to adhere to set policies. The underlying rationale of legislation, delegation, and securitization is to create and support countervailing constituencies with a long-term interest in emissions abatement. First, legislation can provide a transparent governance structure for setting, implementing, and updating carbon policy. Second, delegation insulates interests dedicated to emissions abatement from day-to-day politics while preserving the capacity for flexible adjustments. The institutional mandate may define monitoring and advisory duties. It may also delegate the authority to set policy on government's behalf to an independent carbon agency. Third, securitization protects investors' stakes in carbon markets by entrenching commitment in enforceable contracts. In

particular, put-options on emission allowances fit well with the institutional setting of cap-and-trade systems. In sum, these strategies may help to reduce regulatory uncertainty.

Chapter 4 quantitatively assesses the optimal degree of commitment to a future carbon policy if damages from climate change are uncertain. It finds that the common remedy to time inconsistency, credible commitment to an ex-ante optimal target, is no longer optimal. Under uncertainty, intermediate levels of commitment that offer a balance between commitment and flexibility maximize expected welfare. Credible commitment to an adjustment-rule can maximize social welfare and be established by means of legislation or delegation. Legislation of transparent and accountable procedures is particularly important because of the difficulty to impartially observe key parameters of the adjustment rule such as climate damages or the outcomes of international negotiations.

How can a state address regulatory uncertainty in international climate finance when there is no external enforcement mechanism?

Taking a look at climate policy transactions not within but between states, Chapter 5 provides an argument for why transaction costs in international climate finance will form a significant part of global mitigation cost. It finds that the total economic cost of mitigating climate change through actions in developing countries not only depends on the costs of technologies but also on the quality of institutions that will be available for managing transfers and implementing actions.

Transaction costs rise with the level of uncertainty among transacting parties and include the costs of negotiating, implementing, and monitoring transfers as well as any concomitant inefficiencies that arise from the choice of governance structures. Alignment with recipient institutions suffers from weak recipient capacities and the infeasibility of contract enforcement at the international level. Donor governments respond to uncertainty by delegating the provision of climate finance actions to bilateral and multilateral organizations. Among donors, harmonization of transfers is hampered by the multiplicity of political objectives, resulting in fragmentation of projects and proliferation of organizations. The delivery of climate finance through many small projects from many different donors further burdens the institutional capacity of recipient countries. A broken feedback loop between donor and recipient constituencies provides agents in the process with weak incentives to use climate finance in the most effective way.

Without significant institutional innovation, transaction costs have the potential to severely undermine the effectiveness of mitigation finance. The net-benefit of pushing climate finance through the international aid system should therefore be weighted against the opportunity cost of this strategy. The acknowledgment of transaction costs will result in a different allocation of climate finance than conventional economic models suggest. It might even become efficient to redirect investment for emissions abatement to developed countries where institutions are more reliable and contracting uncertainties less pervasive.

Transaction costs can be addressed if there is enough political will for institutional innovation. Room for improvement can be expected in particular in the clarity and measurability of climate finance objectives, and monitoring, reporting, and verification procedures. The emerging climate finance architecture could be made to profit from the hard-earned lessons of development cooperation. But attempts to craft new institutions that keep transaction costs in check put considerable strain on UNFCCC negotiations as they involve the transfer of state sovereignty. If the extent to which transaction costs accrue and the reason they do so are both known, policymakers might be able to address them more effectively.

What are the limits of a new institutional view on climate policy?

The notion of neoclassical optimality has been criticised for comparing real-world outcomes with unattainable outcomes of a transaction-costless world. New institutional theorists instead advocate a concept of efficiency that embodies transactions costs which can be used to evaluate feasible alternative institutions that could yield social gains net of the costs of reorganisation. But this perspective, too, suffers from some severe limitations.

First, scholars are likely to complain about the vagueness and broadness of the concept of transaction costs. The definition underpinning this thesis, the property rights definition of transaction costs, is so broad that it lacks the edge of a focused perspective with clear conceptual boundaries. Second, practitioners are likely to complain about some of the conclusions of the new institutional view. The discovery of transactional constraints often yields the insight that the existing institutional arrangement is the only feasible one given the current distribution of property rights in the political system. It shows the need to accept some imperfections, and toleration of a slow process of coping using whatever instruments are at hand, economic and political. This insight might not always be satisfying if one seeks quick fixes. Nevertheless, I would argue that a comprehensive understanding of the problem is a necessary condition for exploring feasable solutions.

Third, the proposition of Williamsonian theory that agents are always interested and able to minimize transaction costs seems inconsistent with the assumption of bounded rationality. Sub-optimal institutions will continue to exist because institutional architects, too, do not foresee all future contingencies of their actions. Moreover, transaction cost economics tends to disregard cultural, social, and other dimensions of human conduct because it focuses on a narrowly defined functional value of institutions. Some institutional arrangements may be primarily established to meet policy goals other than economic efficiency. It is hence important to be crystal clear about the objectives of an institutional arrangement before one conducts an analysis over how efficient or cost-effective the arrangement is.

Taking these limitations into account, a new institutional view on climate policy still offers valuable insights. While neoclassical analysis offers the advantage of capturing the production costs of alternative technology mixes, a perspective in the tradition of new

institutional economics might help to complement the picture by focusing on the transaction costs of alternative institutional arrangements. Since climate change is in its essence a collective action problem, exploring transaction costs might bring scientific policy advisers in a better position to understand when and how institutions can provide incentives for cooperation.

The science-policy gap

Finally, I conclude with some brief thoughts on the relationship between science and policy and my role as a scientist as I have perceived it while working on my PhD thesis. At a number of occasions, I was given the opportunity to directly engage with stakeholders and policymakers to discuss the policies they seek and their constraints in implementing them. For instance, my research on national carbon policy benefitted from discussions with the Working Group on Climate Policy of the Federation of German Industry, the Sub-committee on Emissions Trading of the German Environment Ministry, and the parliamentary task force '*Klimaschutzgesetz*' of the Social Democratic Party in the German Bundestag. The research on international climate finance benefitted from a five months traineeship in the climate finance unit of the European Commission in Brussels where I had the opportunity to directly observe and interview policymakers during their daily business. In retrospect, what I have learned from this exposure to policymaking individuals and organizations is that the relationship between science and policy, as far as *institutional* questions are concerned, resembles more a wide gap than a narrow interface and that the one to blame for this divide is the scientific advisor, not the policymaker.

Being in touch with policymakers is necessary if one wants to understand the problem one wishes to 'solve' with scientific advice. Otherwise, advisors might target the wrong problem. But the more an advisor learns about the institutional constraints of policymakers, the less able she will be to offer 'solutions'. Eventually, the advisor will know as much about the problem and institutional constraints as policymakers know themselves. On the other hand, if the advisor remains ignorant about the problem in all its facets, she might be able to propose a 'solution' that violates some institutional constraints but promotes others. Depending on whose property rights the proposed institutional change violates or promotes, some policymakers will hail its cleverness while others will stress its shortcomings. The policy relevance of advice is hence inversely related to its feasibility in a democratic process. Scientists that are unaware of this relationship might become drawn deeper into the political process than they might want to wish for.

After all, it seems that the Coase theorem, and similarly the two fundamental theorems of welfare economics, is an intellectual trick that allows economists to ignore institutions and transaction costs. If the Coase theorem was true, if the set of information and institutions were complete and transaction costs were zero, economists could recommend Pareto-improving interventions without having to say anything about how resources shall initially

be distributed in the system. However, an honest appreciation of incomplete information and institutions and resulting transaction costs in the political and economic process would necessitate evaluating distributional choices from an economic perspective because they now gain relevance for allocative efficiency. With transaction costs, the bargaining process does not guarantee that property rights flow to their highest value use. The acknowledgment of transaction costs limits the set of questions economists can answer without having to make explicit normative recommendations over who should get how much. The frontier between economics and politics becomes even more blurred than it already is. Given this epistemological dimension of transaction costs, philosophers of science too might have some interesting things to say about the relationship between climate policy, the state, and the problem of credible commitment.

Appendix

Statement of contribution

The chapters of this thesis are the result of collaborations between the candidate and his advisor, Prof. Dr. Ottmar Edenhofer, and other colleagues. The candidate has made significant contributions to the contents of all six chapters, from conceptual design to writing.

Chapters 1 and 6 were outlined and written by the candidate. The authors of all remaining chapters are indicated in Table 1 below with the name of the candidate in bold letters. In chapter 2, the candidate provided the conceptual design and the majority of the text. The figure and the tables were mainly developed by Christian Flachsland. In chapter 3, the candidate developed the original idea, the conceptual design, the outline of the argument as well as the majority of the text. It was written jointly with Christian Flachsland, while Robert Marschinski contributed in extensive discussions and to the final editing of the manuscript. In chapter 4, the candidate provided the qualitative discussion of commitment devices (final section). Michael Jakob provided the formal model as well as the majority of the text. In chapter 5, the candidate developed the original idea and outline of the argument as well as the majority of the text. Katrin Enting contributed in discussions and provided editing as well as some parts of the text.

Chapter	Publication reference
#2	**Brunner, S.**, C. Flachsland, O. Edenhofer (2011): Domestic Emissions Trading Systems. In: Gang, Stern, Edenhofer, Shanda, Eklund, Ackerman, Li and Hallding (eds.): *The Economics of Climate Change in China*. Earthscan.
#3	**Brunner, S.**, C. Flachsland, R. Marschinski (2012): Credible commitment in carbon policy. *Climate Policy*: 12(2).
#4	Jakob, M., & **S. Brunner**: Commitment under uncertainty – an adjustment rule for climate policy. Revised manuscript submitted to *Energy Policy*.
#5	**Brunner, S.,** & K. Enting: The neglected side of global mitigation costs. Manuscript submitted to *Global Environmental Change*.

Table 1: Chapters of cumulative thesis related to original publications

Tools and resources

If not stated otherwise, all text, tables, and figures were produced with Microsoft Office Word, Excel, and PowerPoint 2003/2010. In Chapter 2, Figure 1 was made using Software Visio 2000. In Chapter 4, calculations were made using MATLAB, version 7.10 (R2010) from MathWorks.