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Chapter 15

National and Sub-national Policies and Institutions

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Title:	National and Sub-national Policies and Institutions	
Author(s):	CLAs:	Eswaran Somanathan, Thomas Sterner, Taishi Sugiyama
	LAs:	Donald Chimanikire, Navroz K. Dubash, Joseph Kow Essandoh-Yeddu, Solomone Fifita, Lawrence Goulder, Adam Jaffe, Xavier Labandeira, Shunsuke Managi, Catherine Mitchell, Juan Pablo Montero, Fei Teng, Tomasz Zylicz
	CAs:	Arild Angelsen, Kazumasu Aoki, Kenji Asano, Michele Betsill, Rishikesh Ram Bhandary, Nils-Axel Braathen, Harriet Bulkeley, Dallas Burtraw, Ann Carlson, Luis Gomez-Echeverri, Erik Haites, Frank Jotzo, Milind Kandlikar, Osamu Kimura, Gunnar Köhlin, Hidenori Komatsu, Andrew Marquard, Michael Mehling, Duane Muller, Luis Mundaca, Michael Pahle, Matthew Paterson, Charles Roger, Kristin Seyboth, Elisheba Spiller, Christoph von Stechow, Paul Watkiss, Harald Winkler, Bridget Woodman
	REs:	Martin Jänicke, Ronaldo Seroa da Motta, Nadir Mohamed Awad Suliman
	CSA:	Rishikesh Ram Bhandary

Chapter 15: National and Sub-National Policies and Institutions

Contents

Executive Summary

Since AR4, though there has been a marked increase in national policies and legislation on climate change, these policies, taken together, have not yet achieved a substantial deviation in emissions from the past trend. Many reference scenarios (those without additional policies to reduce emissions) show concentrations that exceed 1000 ppmv CO2-e by 2100, which is far from a concentration with a likely probability of maintaining temperature increases below 2C this century. Transformation scenarios suggest that a wide range of environmentally effective policies could be enacted that would be consistent with such goals. This chapter assesses national and sub-national policies and institutions to mitigate climate change in this context. It assesses the strengths and weaknesses of various mitigation policy instruments and policy packages and how they may interact either positively or negatively. Sector-specific policies are assessed in greater detail in the individual sector chapters (7-12). Major findings are summarized as follows. [15.1]

The appropriate design of institutions, governance structures and policy instruments are important for climate change mitigation (*limited evidence, medium agreement)*. By shaping appropriate incentives, creating space for new stakeholders in decision making-- such as representatives of new industries and technologies, and by transforming the understanding of policy choices, institutional and governance changes can accelerate a transition to low-carbon paths, while institutions inherited unchanged from the past can perpetuate lock-in to high-carbon development paths. [15.2, 15.6]

There has been a considerable increase in national and sub-national plans and strategies to address climate change since AR4 *(medium evidence, high agreement)*. These plans and strategies are in their early stages in many countries, and there is inadequate evidence to assess whether and how they will result in appropriate institutional and policy change, and therefore, their impact on future emissions. However, theories of institutional change suggest they could play a role in shaping incentives, political contexts and policy paradigms in a way that encourages emissions reductions in the future [15.1, 15.2] [15.1, 15.2]

Sector-specific policies have been more widely used than economy-wide policy instruments *(medium evidence, high agreement)*. Although economic theory suggests that economy-wide market-based policies are generally more cost-effective, political economy constraints often make those policies harder to achieve than sectoral policies Sector-specific policies may also be needed to overcome sectoral market failures that price policies do not address. For example, building codes can require publicly funded energy efficient investments where private investments would otherwise not exist. Sector approaches also allow for packages of complementary policies, as, for example, in transport, where pricing policies that raise the cost of carbon-intensive forms of private transport are more effective when backed by public investment in viable alternatives [15.1, 15.2, 15.5, 15.8, 15.9]

Regulatory approaches and information measures are widely used, and are often environmentally effective, though debate remains on the extent of their environmental impacts and cost effectiveness *(medium evidence, medium agreement)*. Examples include energy efficiency standards and labeling programs that can help consumers make better-informed decisions. While such approaches often work at a net social benefit, the scientific literature is divided on whether such policies are implemented with negative private costs to firms and individuals. Since AR4 there has been continued investigation into "rebound" effects that arise when higher efficiency leads to lower energy prices and greater consumption. There is general agreement that such rebound effects exist, but there is low agreement in the literature on the magnitude. [3.9.5, 8.3, 9.7.2.4, 15.5.4, 15.5.5]

Fuel taxes are an example of a sector-specific policy and are often originally put in place for objectives such as revenue – they are not necessarily designed for the purpose of climate

mitigation) (high confidence). In Europe where fuel taxes are highest they have contributed to reductions in carbon emissions from the transport sector of roughly 50% for this group of countries. The short-run response to higher fuel prices is often small, but long-run price elasticities are quite high: or roughly-0.6 to -0.8. This means that in the long run, 10% higher fuel prices correlate with 7% reduction in fuel use and emissions. In the transport sector, taxes have the advantage of being progressive or neutral in most countries and strongly progressive in low-income countries. [15.5.2]

Reduction of subsidies to fossil energy can result in significant emission reductions at negative social cost (*high confidence).* [15.5.2] Although political economy barriers are substantial, many countries have reformed their tax and budget systems to reduce fuel subsidies, that actually accrue to the relatively wealthy, and utilized lump-sum cash transfers or other mechanisms that are more targeted to the poor. [15.5.3]

Cap and trade systems for greenhouse gases are being established in a growing number of countries and regions *(limited evidence, medium agreement)*. Their environmental effect has so far been limited because caps have either been loose or have not yet been binding. There appears to have been a trade-off between the political feasibility and environmental effectiveness of these programs, as well as between political feasibility and distributional equity in the allocation of permits. Greater environmental effectiveness through a tighter cap may be combined with a price ceiling that makes for political feasibility. [15.5.3]

Carbon taxes have been implemented in some countries and – alongside technology and other policies – have contributed to decoupling of emissions from GDP *(high confidence)*. Differentiation by sector, which is quite common, reduces cost-effectiveness that arises from the changes in production methods, consumption patterns, lifestyle shifts, and technology development, but it may increase political feasibility, or be preferred for reasons of competitiveness or distributional equity. In some countries, high carbon and fuel taxes have been made politically feasible by refunding revenues or by lowering other taxes in an environmental fiscal reform. [15.2, 15.5.2, 15.5.3]

The emission abatement effects of a carbon tax are additive with other policies such as subsidies, whereas those of a cap-and-trade policy are not *(high confidence)*. If a cap and trade system has a sufficiently stringent cap then other policies such as renewable subsidies have no further impact on total emissions (although they may affect costs and possibly the viability of more stringent future targets). If the cap is loose relative to other policies, it becomes irrelevant. This is an example of a negative interaction between policy instruments. Since other policies cannot be "added on" to a cap-and-trade system, if it is to meet any particular target, a sufficiently low cap is necessary. [15.7]

There is a distinct role for technology policy in GHG mitigation, as a complement to other mitigation policies (*high confidence)*. Properly implemented technology policies reduce the cost of achieving a given environmental target. Technology policy will be most effective when technology-push policies (e.g. publicly funded R&D) and demand-pull policies (e.g. governmental procurement programs or performance regulations) are used in a complementary fashion (*robust evidence, high agreement)*. [15.6] While technology-push and demand-pull policies are necessary, they are unlikely to be sufficient without complementary framework conditions. Managing social challenges of technology policy change may require innovations in policy and institutional design, including building integrated policies that make complementary use of market incentives, authority and norms (*medium evidence, medium agreement*). [15.6.5].

Since AR4, a large number of countries and sub-national jurisdictions have introduced support policies for renewable energy such as FIT and RPS. These have promoted substantial diffusion and innovation of new energy technologies such as wind turbines and photovoltaic panels, but have raised questions about their economic efficiency, and introduced challenges for grid and market integration (7.12, 15.6).

Worldwide investment in research in support of GHG mitigation is small relative to overall public research spending (*medium evidence, medium agreement*). The effectiveness of research support will be greatest if it is increased slowly and steadily rather than dramatically or erratically It is important that data collection for program evaluation to be built into technology policy programs, because there is very little empirical evidence on the relative effectiveness of different mechanisms for supporting the creation and diffusion of new technologies. [15.6.2, 15.6.5]

Public finance mechanisms reduce risks that deter climate investments (*high confidence*). The future value of carbon permits created by economic instrument such as cap and trade may, for example, not be accepted as sufficiently secure by banks. Government public finance mechanisms to reduce risks include: debt and equity mechanisms, carbon finance and innovative grants. [15.12]

Government planning and provision can facilitate shifts to less energy and carbon-intensive infrastructure and lifestyles *(high confidence)*. This applies particularly when there are indivisibilities in the provision of infrastructure as in the energy sector (e.g. for electricity transmission and distribution or district heating networks where projects must be built at very large scale if they are to be built at all); in the transport sector (e.g. for non-motorized or public transport), and in urban planning. The provision of adequate infrastructure is important for behavioural change *(medium evidence, high agreement)* [15.5.6].

Successful voluntary agreements between governments and industries to reduce emissions are characterized by a strong institutional framework with capable industrial associations *(medium evidence, medium agreement)***.** The strengths of voluntary agreements are speed and flexibility in phasing measures, and facilitation of barrier removal activities for energy efficiency and low emission technologies. Regulatory threats, even though the threats are not always explicit, are also an important factor for firms to be motivated. There are few environmental impacts without a proper institutional framework *(medium evidence, medium agreement).* [15.5.5]

Synergies and tradeoffs between mitigation and adaptation policies may exist in the land-use sector *(medium evidence, medium agreement).* For other sectors such as industry and power, the connections are not obvious. [15.11]

The ability to undertake policy action requires information, knowledge, tools and skills, and therefore capacity building is central both for mitigation and to the sustainable development agenda. *(medium evidence, high agreement)*. The needs for capacity building include: capacity to analyse the implications of climate change, capacity to formulate, implement and evaluate policies, capacity to take advantage of external funding and flexible mechanisms and to make informed choices of the various capacity building modalities. [15.10]

Mainstreaming climate change into development planning has helped yield financing for various climate change policy initiatives *(medium evidence, medium agreement)*. Among developing and some least developed countries, an emerging trend is the establishment of national funding entities dedicated to climate change. While diverse in design and objectives, they tap and blend international and national sources of finance, thereby helping to improve policy coherence and address aid fragmentation. Financing climate adaptation and mitigation in developing countries is crucial from the viewpoint of welfare and equity. *(medium evidence, high agreement)* [15.12]

Gaps in knowledge: The fact that various jurisdictions produce various policy instruments influenced by co-benefits and political economy and that they interact in complex manners makes it difficult to evaluate the economic and environmental effectiveness of individual policy instrument as well as policy package of a nation. Most importantly, it is not known with certainty how much an emission reduction target may cost to the economy in the real world in comparison to the “first best” optimal solution estimated by economic models in other chapters in this report. Costs may be under-stated or over-stated.

15.1 Introduction

This chapter assesses national and subnational mitigation policies and their institutional settings. There has been a marked increase in national policies and legislation on climate change since the AR4 with a diversity of approaches and a multiplicity of objectives [Section 15.2]. However, Figure 1.9 of Chapter 1 suggests that these policies, taken together, have not yet achieved a substantial deviation in emissions from the past trend. Limiting concentrations to levels that would be consistent with a likely probability of maintaining temperature increases below 2C this century (scenarios generally in the range of 430-480 ppmv CO2-e) would require that emissions break from these trends and be decreased substantially. In contrast, concentrations exceed 1000 ppmv CO2-e by 2100 in many reference scenarios (that is, scenarios without additional efforts to reduce emissions).

The literature on transformation scenarios provides a wide range of CO2 shadow price levels consistent with these goals, with estimates of less than $50/tCO2 in 2020 in many studies and exceeding $100/tCO2 in others, assuming a globally-efficient and immediate effort to reduce emissions. These shadow prices exhibit a strongly increasing trend thereafter. Policies and instruments are assessed in this light.

Section 15.2 assesses the role of institutions and governance. Section 15.3 lays out the classification of policy instruments and packages while 15.4 discusses the methodologies used to evaluate policies and institutions. The performance of various policy instruments and measures are individually assessed in Section 15.5 and 15.6.

The two main types of economic instruments are price instruments, that is, taxes and subsidies, (including removal of subsidies on fossil fuels), and quantity instruments -- emission trading systems. These are assessed in subsections 15.5.2 and 15.5.3 respectively. An important feature of both these instruments is that they can be applied at a very broad, economy-wide scale. This is in contrast to the regulation and information policies and voluntary agreements which are usually sector-specific. These policies are assessed in sections 15.5.4, 15.5.5 and 15.5.7. Government provision and planning is discussed in 15.5.6. The next section 15.6 provides a focused discussion on technology policy including research and development and the deployment and diffusion of clean energy technologies. In addition to technology policy, longer-term effects of the policies assessed in Section 15.5 are addressed in Section 15.6.

Both these sections, 15.5 and 15.6, bring together lessons from policies and policy packages used at the sectoral level from Chapters 7 (energy), 8 (transport), 9 (buildings), 10 (industry), 11 (Agriculture, forestry and land use) and Chapter 12 (human settlements, infrastructure, and spatial planning).

The following sections further assess the interaction among policy instruments, as they are not usually used in isolation and the impacts of particular instruments depend on the entire package of policies and the institutional context. Section 15.7 reviews interactions, both beneficial and harmful, that may not have been planned. The presence of such interactions is in part a consequence of the multi-jurisdictional nature of climate governance as well as the use of multiple policy instruments within a jurisdiction. Section 15.8 examines the deliberate linkage of policies across national and subnational jurisdictions.

Other key issues are further discussed in dedicated sections. They are: the role of stakeholders including NGOs (15.9), capacity building (15.10), links between adaptation and mitigation policies (15.11), and investment and finance (15.12). Gaps in knowledge are collected in 15.13.

15.2 Institutions and Governance

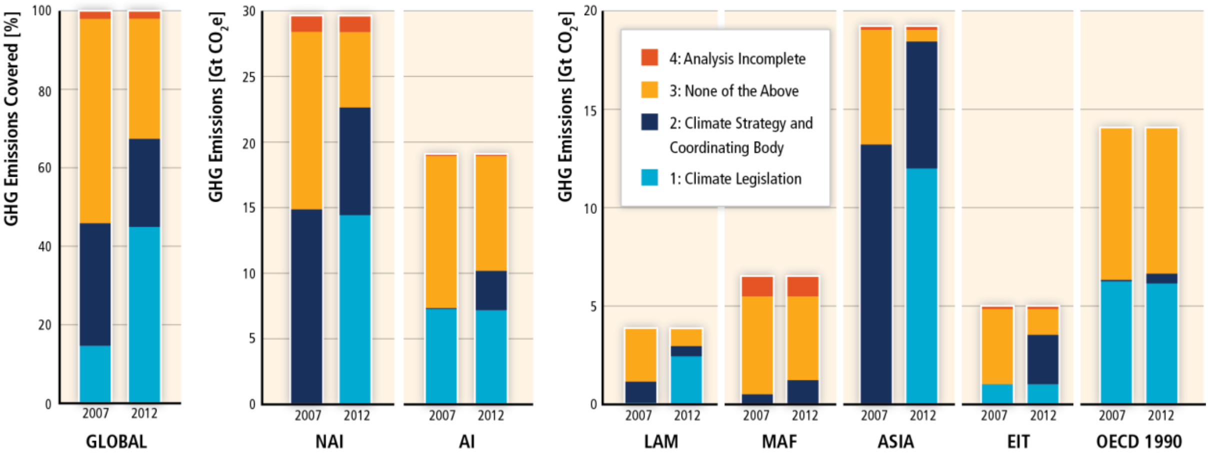
15.2.1 Why institutions and governance matter

Institutions and processes of governance (see Glossary for definitions) shape and constrain policy-making and policy implementation in multiple ways relevant for a shift to a low carbon economy. First, institutions – understood as formal rules and informal norms -- set the incentive structure for economic decision-making (North, 1991), influencing, for example, decisions about transportation investments, and behavioural decisions relevant to efficient energy use. Second, institutions shape the political context for decision making, empowering some interests and reducing the influence of others (Steinmo et al., 1992; Hall, 1993). Harrison (2012) illustrates this with respect to environmental tax reform in Canada. Third, institutions can also shape patterns of thinking and understanding of policy choices – through both normative and cognitive effects (Powell and DiMaggio, 1991). These effects can result in dominant policy paradigms – ideas, policy goals and instruments -- that favour some actions and exclude others from consideration (Radaelli and Schmidt, 2004). For example, existing energy systems are likely to remain in place without appropriate institutional change (Hughes, 1987) and changes in discourse, which would perpetuate existing technologies and policies and lock out new ones (Unruh, 2000; Walker, 2000). More generally, a mismatch between social-ecological context and institutional arrangements can lead to a lack of fit and exert a drag on policy and technological response (Young, 2002).

15.2.2 Increase in government institutionalization of climate mitigation actions

There has been a definite increase since AR4 in formal governmental efforts to promote climate mitigation. These efforts are diverse in their approach, scale, and emphasis, and take the form of legislation, strategies, policies, and coordination mechanisms. Many of these are relatively recent, and often in the design or early implementation stage. As a result, it is premature to evaluate their effectiveness and there is insufficient literature as yet that attempts to do so. Since global greenhouse gas emissions have continued to increase in recent years (Chapter 6 and Section 15.1) it will be important to closely monitor this trend to evaluate if policies and institutions created are sufficiently strong and effective to lead to the reductions required to stabilize global temperature, for instance, at the 2 degree target, This section reviews national centralized governmental actions, while 15.2.3 discusses sectoral actions and 15.2.5 examines the roles of other stakeholders including non-state actors.

A review of climate legislation and strategy in almost all UN member states shows that there has been a substantial increase in these categories between 2007 and 2012 (Dubash et. al., (2013)) (See Figure 15.1). Dubash et al (2013) define climate legislation as mitigation-focused legislation that goes beyond sectoral action alone, while climate strategy is defined as a non-legislative plan or framework aimed at mitigation that encompasses more than a small number of sectors, and that includes a coordinating body charged with implementation. International pledges are not included. By these definitions, 39% of countries, accounting for 73% of population and 67% of greenhouse gas emissions, were covered by climate law or strategies in 2012, an increase from 23% of countries, 36% of population, and 45% of emissions in 2007. There are also strong regional differences, with Asia and Latin America recording the fastest rate of increase. Taken as a block, in 2012, 49% of current emissions from the developing world regions of Asia, Africa and Latin America were under climate law and 77% of emissions were under either law or strategy, while for the developed world regions of OECD (1990) and Economies in Transition the equivalent numbers are 38% and 56%. Finally, while the number of countries with climate legislation increased marginally from 18% to 22% over this period, the number of countries with climate strategies increased from 5% to 18% suggesting many more countries are adopting a strategy-led approach. (For regional aggregations see Annex II.10)



	GLOBAL 2007	GLOBAL 2012	NAI 2007	NAI 2012	AI 2007	AI 2012
1	7 (15%)	22 (44%)	0 (0%)	14 (49%)	7 (38%)	7 (38%)
2	15 (30%)	11 (23%)	15 (50%)	8 (28%)	0 (0%)	3 (16%)
3	25 (52%)	15 (30%)	14 (46%)	6 (19%)	12 (61%)	9 (46%)
4	1 (3%)	1 (3%)	1 (4%)	1 (4%)	0 (1%)	0 (1%)

	LAM 2007	LAM 2012	MAF 2007	MAF 2012	ASIA 2007	ASIA 2012	EIT 2007	EIT 2012	OECD 1990 2007	OECD 1990 2012
1	0 (2%)	2 (63%)	0 (0%)	0 (0%)	0 (0%)	12 (62%)	1 (20%)	1 (20%)	6 (44%)	6 (44%)
2	1 (28%)	1 (13%)	1 (8%)	1 (19%)	13 (69%)	6 (34%)	0 (0%)	3 (50%)	0 (0%)	0 (3%)
3	3 (70%)	1 (23%)	5 (76%)	4 (65%)	6 (30%)	1 (3%)	4 (76%)	1 (26%)	8 (55%)	7 (53%)
4	0 (0%)	0 (0%)	1 (16%)	1 (16%)	0 (1%)	0 (1%)	0 (3%)	0 (3%)	0 (0%)	0 (0%)

Figure 15.1 National Climate legislation and strategies in 2007 and 2012.[1] Reproduced from Dubash et al, (2013). In this figure, climate legislation is defined as mitigation-focused legislation that goes beyond sectoral action alone. Climate strategy is defined as a non-legislative plan or framework aimed at mitigation that encompasses more than a small number of sectors, and that includes a coordinating body charged with implementation. International pledges are not included, nor are sub-national plans and strategies. The panel shows proportion of GHG emissions covered.

Climate legislation and strategies follow a wide diversity of approaches to operationalization and implementation. The imposition of carbon prices is one approach widely discussed in the literature (See Section 15.5) but less frequently implemented in practice. Examples include the European Union's Emissions Trading Scheme (See 14.4.2) or setting of carbon taxes (see Section 15.5.2). One study of the 19 highest emitting countries finds that 6 have put in place some form of carbon price, while 14 have put in place both regulation and other economic incentives for greenhouse gas mitigation, (Lachapelle and Paterson, 2013). Common explanations for this variation are in terms of the novelty of emissions trading (although emissions trading has been in practice implemented much more widely than carbon taxation), the legitimacy problems faced by emissions trading (Paterson, 2010), or political contestation over increased taxation (see for example Laurent, (2010), on the French case, Jotzo, (2012) for Australia, or Jagers and Hammar, (2009), for evidence that popular support for carbon taxes in Sweden depend on how it is framed in popular debate), and lobbying by fossil-fuel or energy-intense industry lobbies (Bailey et al., 2012; Sarasini, 2013).

More generally speaking, policy instruments have often been sector-specific. Economy-wide instruments, even when implemented, have had exemptions for some sectors, most commonly those most exposed to international trade. The exemptions have arisen because national policies have been developed under the strong influence of sectoral policy networks (Compston, 2009) and many stakeholders therein – including firms and NGOs – influence the policy to promote their interests (Helm, 2010). This phenomenon undermines the overall cost-effectiveness of climate policy (Anthoff and Hahn, 2010) although it may help further other objectives such as equity and energy security.

Another approach follows a model of national-level target backed by explicit creation of institutions to manage performance to that target. In China, for example, a 'National Leading Group on Climate

[1] Number of countries and GHG emissions covered (NAI: Non Annex I countries (developing countries), AI: Annex I countries (developed countries), LAM: Latin America, MAF: Middle East and Africa, ASIA: Asia, EIT: Economies in transition, OE90: OECD of 1990)

Change' in June 2007, housed in the apex National Development and Reform Commission and chaired by the premier (Tsang and Kolk, 2010a) coordinates the achievement of targets set in the subsequent National Climate Change Programme. The Chinese examples illustrate a broader point emerging from a cross-country study that implementation of climate legislation and plans are, in at least some cases, drawing powerful finance and planning departments into engagement with climate change (Held, et al., 2013).

Another approach is to establish dedicated new climate change bodies that are substantially independent of the executive and that seek to coordinate existing government agencies through a variety of levers. The leading example of this approach is in the UK, where a dedicated Climate Change Committee analyzes departmental plans and monitors compliance with five-year carbon budgets (U.K., 2008; Stallworthy, 2009).Instead of direct executive action, as in the Chinese case, this approach relies on analysis, public reporting and advice to government. Following the UK example, Australia has established an independent Climate Change Authority to advise the government on emission targets and review effectiveness of its Carbon Pricing Mechanism (Keenan et al., 2012).

15.2.3 Climate Mitigation through Sectoral Action

While there is no systematic study of implementation of climate plans, case study evidence suggests that these plans are frequently operationalised through sectoral actions. There are a variety of ways through which national plans interface with sectoral approaches to mainstream climate change. In some cases, there is a formal allocation of emissions across sectors. For example, in Germany, mitigation efforts were broken down by sectors for the period between 2008 to 2012, with the national "Allocation Act 2012" specifying emissions budgets for sectors participating in the EU Emissions Trading Scheme as well as the remaining sectors (Dienes, 2007; Frenz, 2007).More typically, climate mainstreaming occurs through a sector by sector process led by relevant government departments, as in France (Mathy, 2007), India (Dubash, 2011; Atteridge et al., 2012) and Brazil (da Motta, 2011a; La Rovere et al., 2011).

In some cases, the sectoral process involves a role for stakeholders in engagement with government departments. In France, sectoral approaches are devised at the central level through negotiation and consultation between multiple ministries, experts, business and NGOs. According to at least one analysis, this approach risks a dilution of measures through the influence of lobbies that may lose from mitigation actions (Mathy, 2007). In Brazil, sector specific approaches are developed by sectoral ministries complemented by a multi-stakeholder forum to solicit views and forge consensus (Hochstetler and Viola, 2012; Viola and Franchini, 2012; Held et al., 2013a).

In some cases, climate change considerations bring about changes in long-standing patterns of sector governance. In South Africa, for example, the Copenhagen pledge led to a process of reconsidering South Africa's integrated resource plan for electricity, to include carbon reduction as one among multiple criteria (Republic of South Africa, 2011a). In India, the establishment of national sectoral 'missions' had the effect of creating new institutional mechanisms in the case of the National Solar Mission, or of raising the profile and importance of particular ministries or departments as in the example of the Bureau of Energy Efficiency (Dubash, 2011). In other cases, climate mainstreaming was facilitated by prior political shifts in governance of a sector. Brazil's climate approach particularly emphasizes the forest sector (da Motta, 2011b; La Rovere, 2011). Progress on the Brazilian plan was enabled by prior domestic political consensus around a far-reaching Forest Code (Hochstetler and Viola, 2012).)

15.2.4 Co-Benefits as a driver of mitigation action

The importance of co-benefits – both development gains from climate policy and climate gains from development policy – emerge as a particularly strong rationale and basis for sectoral action. As

Table **15.1** shows, an inventory of sectoral action on climate change drawn from Chapter 7-12) is linked to a wide range of co-benefits, encompassing ranging from economic, social and environmental effects.

This perception is reinforced by comparative case studies and specific country studies. A comparative study finds that co-benefits is an important driving force for climate mitigation policies across large rapidly industrialising countries (Bailey and Compston, 2012a), a finding that is supported by country level studies. India's National Action Plan on Climate Change (NAPCC), for example, is explicitly oriented to pursuit of co-benefits, with climate mitigation understood to be the secondary benefit emerging from development policies. The linkage between energy security and climate mitigation is particularly important to winning broader political support for action on climate mitigation (Dubash, 2011; Fisher, 2012). A similar trend is apparent in China (Oberheitmann, 2008), where provincial implementation of targets is enabled by linking action to local motivations, notably for energy efficiency (Teng and Gu, 2007; Richerzhagen and Scholz, 2008a; Qi et al., 2008; Tsang and Kolk, 2010b; Kostka and Hobbs, 2012).Tsang and Kolk (2010a) go so far as to say that Chinese leaders essentially equate climate policy with energy conservation. Kostka and Hobbs (2012) identify three ways in which this alignment of global and local objectives happens: interest bundling, through which objectives of political institutions are tied to local economic interests; policy bundling, to link climate change with issues of local political concern; and framing in ways that play to local constituencies.

The concept of "nationally appropriate mitigation actions" (NAMAs) has a conceptual connection to the idea of co-benefits. NAMAs are intended to be mitigation actions that are "nationally appropriate" in the sense that they contribute to development outcomes. NAMAs therefore provide a possible mechanism for connection of national policies and projects to the global climate regime, although the mechanisms through which this will be accomplished are yet to be fully articulated (see Box 15.1). Another, related mechanism is the explicit formulation in many countries of "low emissions development strategies" that seek to integrate climate and development strategies (Clapp et al., 2010).

A roadmap for the co-benefits and adverse side effects from sectoral mitigation measures most prominently discussed across chapters 7 to 12 are listed in three columns: economic, social, and environmental. Each column shows the range of effects on objectives/concerns beyond mitigation discussed in Chapters 7-12 for that category. For example, energy security is categorized in the column of "economic" and addressed in section 7.9, 8.7, 9.7, 10.8, 11.13.6 and 12.8.

Table 15.1: Roadmap for the assessment of potential co-benefits and adverse side effects from mitigation measures on additional objectives/concerns in the sector chapters (7-12). For overview purposes, only those effects are shown that are relevant for at least two sectors. For a broader synthesis of the literature assessed in this report, see section 6.6.

Economic	Social	Environmental
Energy security (7.9,8.7,9.7,10.8,11.13.6, 12.8) Employment impact (7.9,8.7,9.7,10.8,11.7, 11.13.6) New business opportunity/economic activity (7.9,11.7,11.13.6) Productivity/competitiveness (8.7,9.7,10.9,11.13.6) Technological spill-over/innovation (7.9,8.7,10.8,11.3,11.13.6)	Health impact (e.g. via air quality) (5.7,7.9,8.7,9.7,10.8,11.7,11.13.6,12.8) Energy/mobility access (7.9,8.7,9.7,11.13.6,12.4) (Fuel) Poverty alleviation (7.9,8.7,9.7,11.7,11.13.6) Food security (7.9,11.7,11.13.6/7) Impact on local conflicts (7.9,10.8,11.7.11.13.6) Safety/disaster resilience (7.9,8.7,9.7,10.8,12.8) Quality of life/noise/working conditions (7.9,8.7,9.7,10.8,11.13.6) Gender impact (7.9,9.7,11.7,11.13.6)	Ecosystem impact (e.g. via air pollution) (7.9,8.7,9.7,10.8,11.7, 11.13.6/7,12.8) Land use competition (7.9,8.7,10.8,11.7,11.13.6/7) Water availability/quality (7.9,9.7,10.8,11.7,11.13.6) Biodiversity conservation (7.9,9.7,11.7,11.13.6) Urban heat island effect (9.7,12.8) Resource/material use impact (7.9,8.7,9.7,10.8,12.8)

Box 15.1. Nationally Appropriate Mitigation Actions

The Bali Action Plan (BAP), (1/CP.13, (UNFCCC, 2007)) states that developing countries are called on to take "nationally appropriate mitigation actions" (NAMAs) supported and enabled by technology and finance. NAMAs could, for example, be articulated in terms of national emissions intensity or trajectories, sectoral emissions, or specific actions at sectoral or sub-sectoral levels. As of June 2013, 57 parties had submitted NAMAs to the UNFCCC secretariat.

The design of mechanisms to link NAMAs to global support lead to some complex trade-offs. For example, large scale sectoral NAMAs provide the least scope for leakage (decreased emissions in one sector is undermined by increased emissions in another part of the economy) and the lowest measurement costs (Jung et al., 2010). However, designing NAMAs around transaction costs might run counter to designing them for targeted focus on national development priorities. Exploring the extent of this trade-off and managing it carefully will be an important part of implementing NAMAs.

Much of the writing on NAMAs is focused on the challenges of linking national actions to the international climate framework. Conceptual challenges involved in linking NAMAs to the UNFCCC process include the legal nature of NAMAs (van Asselt et al., 2010), financing of NAMAs and associated concerns of avoiding double counting (Cheng, 2010; Jung et al., 2010; van Asselt et al., 2010; Sovacool, 2011a) and measurement, reporting and verification of (Jung et al., 2010; Sterk, 2010; van Asselt et al., 2010).

While NAMAs pertain particularly to the developing world, co-benefits based arguments are also used in developed countries. In the United States, Gore and Robinson (2009)argue that expansion of municipal scale action is articulated in the form of co-benefits, and is driven by network-based communication and citizen initiative. In Germany, several benefits in addition to climate change have been attributed to the policy for energy transition or "Energiewende," including security of energy supply and industrial policy (Lehmann and Gawel, 2013).

15.2.5 Sub-national Climate Action and Interaction across Levels of Governance

In many countries, the formulation and implementation of national mitigation approaches are further delegated to sub-national levels, with differing levels of central coordination, depending on national contexts and institutions. Comparative analysis of cross-country climate action is insufficiently developed to allow generalization and explanation of different approaches to climate policy.

In some federal systems, national target setting by the central government is followed by further allocation of targets to provinces, often through nationally specific formulae or processes. For example, in the case of Belgium, Kyoto targets were re-allocated to the regional level through a process of negotiation, followed by the preparation of regional climate plans to implement regional targets (Happaerts et al., 2011). Ultimately, since agreement could not be reached on regional targets to meet the national Kyoto targets, the approach relied on offsets were explicitly internalized as part of the national approach to meeting Kyoto targets. In China, national action is defined and monitored by the central government in consultation with provinces, and implementation is delegated to provinces. Targets set in the subsequent National Climate Change Programme as part of the 11th Five Year Plan were implemented through a mechanism of provincial communiqués to track compliance with the target, and provincial leading groups to implement the target (Teng and Gu, 2007; Qi et al., 2008; Tsang and Kolk, 2010b; Held et al., 2011a; Kostka and Hobbs, 2012). A range of policy mechanisms were used to implement this target, such as differential energy prices based on energy efficiency performance, promotion of energy audits, and financial incentives for performance (Held et al., 2011b). Subsequent revised targets have been set for the 12th Five Year Plan.

Other countries represent intermediate cases between central control and decentralization. India has developed a mix of national policies through its National Action Plan on Climate Change, responsibility for which rests with central government ministries, and State Action Plans on Climate Change to be developed and implemented by states (Dubash et al., 2013). While they are predominantly focused on implementing national level directives, there is also sufficient flexibility to pursue state-level concerns, and some states have created new mechanisms, such as the establishment of a Climate Change department in the state of Gujarat, and the establishment of a green fund in Kerala (Atteridge et al., 2012). In France, the EU objectives were adopted as national goals, and through national legislation, all urban agglomerations over 50,000 are required to prepare 'Climate and Energy Territorial Plans' to meet these goals and, additionally, to address adaptation needs (Republique Francaise). Since all other planning processes related to issues such as transport, building, urban planning, energy have to conform to and support these objectives, this approach provides a powerful mechanism to mainstream climate change into local public planning. These plans also form a framework around which private voluntary action can be organized. In Germany, while the federal government initiates and leads climate action, the states or "Länder" have a veto power against central initiatives through representation in the upper house of parliament (Weidner and Mez, 2008). In addition, however, the Länder may also take additional action in areas such as energy efficiency measures, renewable energy development on state property and even through state-wide targets (Biedermann, 2011).

In some cases, climate change considerations bring about changes in long-standing patterns of sector governance. For example, South Africa's Copenhagen pledge led to a process of reconsidering South Africa's integrated resource plan for electricity, to include carbon reduction as one among multiple criteria (Republic of South Africa, 2011b). In India, the establishment of national sectoral 'missions' had the effect of creating new institutional mechanisms in the case of the National Solar Mission, or of raising the profile and importance of particular ministries or departments such as the Bureau of Energy Efficiency (Dubash, 2011). In other cases, climate mainstreaming was facilitated by prior political shifts in governance of a sector. Brazil's climate approach particularly emphasizes the forest sector (da Motta, 2011b; La Rovere, 2011). Progress on the Brazilian plan was enabled by prior domestic political consensus around a far-reaching Forest Code (Hochstetler and Viola, 2012).

In other cases, sub-national jurisdictions seem to be attempting to compensate for the lack of political momentum at the national level (Schreurs, 2008; Dubash, 2011). In the United States, for example, although progress at the federal level has been slow and halting, there have been multiple efforts at sub-national scales, through unilateral and coordinated action by states, judicial intervention, and municipal-scale action (Carlarne, 2008; Rabe, 2009, 2010; Posner, 2010). There are examples of states joining together in creating new institutional mechanisms, such as the Regional Greenhouse Gas Initiative among North-Eastern states in the United States to institute an emission trading programme, and the Western Climate Initiative between California and several Canadian provinces, although both these initiatives have also failed to live up to their original promise (Mehling and Frenkil, 2013). Climate policy in the state of California with its new cap and trade program is particularly worth noting both because of the size of its economy and because California has a history as a pioneer of environmental innovation (Mazmanian et al., 2008; Farrell and Hanemann, 2009).

As detailed further in Section 15.8, cities are particularly vibrant sites of subnational action in some countries, often operating in networks and involving a range of actors at multiple scales (Betsill and Bulkeley, 2006; Gore and Robinson, 2009). For example, in the Netherlands, the central government has established a programme that provides subsidies to municipalities to undertake various measures such as improvements in municipal buildings and housing, improved traffic flow, sustainable energy and so on (Gupta et al., 2007). In Brazil, important cities such as Rio de Janeiro and Sao Paulo have taken specific measures that go beyond national policies. For example, a 2009 Sao Paulo law (No. 13.798) commits the state to undertake mandatory economy-wide GHG emission reduction targets of 20% by 2020 from 2005 levels (Lucon and Goldemberg, 2010). In the U.S., over 1000 cities and municipalities have committed to reaching what would have been the US Kyoto target as part of the Conference of Mayors' Climate Protection Agreement (Mehling and Frenkil, 2013).

Sub-national action on climate change is a mix of bottom-up experimentation and the interaction of top-down guidance with local implementation action. In some cases countries have set in place explicit mechanisms for coordination of national and sub-national action, such as in China and India, but there is insufficient evidence to assess the effectiveness of these mechanisms. More typical is relatively uncoordinated action and experimentation at sub-national level, particularly focused on cities. These issues are discussed further in Section 15.8.

15.2.6 Drivers of National and Sub-national Climate Action

National and sub-national actions are related to domestic political institutions, domestic politics, international influences and ideational factors. Based on data from industrialized countries, a comparative political analysis suggests that proportional representation systems such as those in many EU nations are more likely than first past the post systems to give importance to minority interests on environmental outcomes; systems with multiple veto points, such as the US system, afford more opportunities for opponents to block political action; and in federal systems powerful provinces with high compliance costs can block action, as seems to have occurred in Canada (Harrison and Sundstrom, 2010). Lachapelle and Paterson (2013) use quantitative analysis to substantiate the argument about proportional representation and systems with multiple veto points. They also show that presidential-congressional systems find it systematically more difficult to develop climate change policy than parliamentary systems.

These are, however, only general tendencies; and the specific details of country cases, as well as the possibility of multiple and interacting causal factors, suggests the need for caution in predicting outcomes based on these factors.

In particular, national domestic political factors are also salient. Electoral politics, operating through pressure for action from domestic constituents is a determinant of action as is the cost of compliance (Harrison and Sundstrom, 2010). The role of climate change in electoral strategies developed by political parties, may also play a role in climate governance, although evidence for this effect is available only for developed countries (Carter, 2008; Fielding et al., 2012; Bailey and Compston, 2012b). For example, the compliance costs of carbon pricing were the subject of direct electoral competition between stralia's major political parties in the 2007 and 2010 general elections (Rootes, 2011; Bailey et al., 2012). The presence of substantial co-benefits opportunities and re-framing policy around these opportunities can also influence domestic politics in favour of climate action ((Held et al., 2013b); (Bailey and Compston, 2012b)). Finally, the "type" of state – liberal market, corporatist or developmental -- can shape outcomes (Lachapelle and Paterson, 2013). For example, somewhat counter-intuitively corporatist states (e.g. Germany, South Korea) are more likely to have introduced carbon pricing than states with liberal market policy traditions (e.g. the US, Canada). Conversely, liberal market economies are more likely, as are developmental states (e.g. China), to focus on R&D as a principal policy tool (on the US, see notably Macneil, (2012). These patterns reflect powerful institutional path dependencies and incentives facing actors promoting climate policy in particular countries (Macneil, 2012).

International pressures are also important in explaining state action. Diplomatic pressure, changes in public and private finance that emphasize mainstreaming climate change, and a general trend toward higher fossil-fuel energy prices all are associated with increasing climate action (Held et al., 2013b).

Finally, based on comparative case studies, various ideational factors such as national norms around multilateralism, perceptions of equity in the global climate regime (Harrison and Sundstrom, 2010), and ideas put forward by scientists, international organizations and other voices of authority can also shift domestic politics (Held et al., 2013b).

15.2.7 Conclusion

The evidence on institutional change and new patterns of climate governance is limited, as many countries are in the process of establishing new institutions and systems of governance. However, a few trends are visible. First, there is a considerable increase in government led institutionalization of climate action through both legislation and policy since AR4. The factors driving these changes include international pressures, scope for co-benefits, and changing norms and ideas. The specifics of national political systems also affect country actions. Second, evidence from national cases illustrates considerable diversity in the forms of action. While there are only a few cases of nationally-led economy wide carbon price setting efforts, more common are sectoral approaches to climate mitigation or delegated action to sub-national levels, often embedded within national climate policy frameworks. Third, the promise of 'co-benefits' is often an important stated reason for climate policies and their framing. Fourth, there is a profusion of activity at sub-national levels, particularly urban areas, much of which is only loosely coordinated with national actions. Finally, the diversity of approaches appears to be strongly driven by local institutional and political context, with legislative and policy measures tailored to operate within the constraints of national political and institutional systems.

15.3 Characteristics and classification of policy instruments and packages

This subsection presents a brief and non-exhaustive description of the main policy instruments and packages, using the common classification set by Section 3.8 (Chapter 3). Most of these instruments will be assessed with the common evaluation criteria set by Chapter 3 (see Section 15.5) in most of the remaining parts of this chapter. As indicated in Section 15.2, these instruments are introduced within an institutional context that obviously influences their design and implementation.

15.3.1 Economic Instruments

Economic instruments are sometimes termed "market-based" approaches because prices are employed in environmental and climate change policies. Economic instruments for climate change mitigation include taxes (including charges and border adjustments), subsidies and subsidy removal, and emissions trading schemes. Taxes and subsidies are known as price instruments since they do not directly target quantities, while emission trading schemes, especially cap-and-trade schemes, (see below) are known as quantity instruments. This distinction can be important, as seen in Subsections 15.5.3.8, 15.7.3.2, and 15.7.3.4.

Taxes and charges are ideally defined as a payment for each unit of greenhouse gas released into the atmosphere. In the climate context, they are usually unrelated to the provision of a service and are thus known as taxes rather than charges. They can be levied on different tax bases, whereas tax rates, given the global and uniform characteristics of the taxed emissions, usually do not show spatial variation (OECD, 2001). In the last years many taxes on GHG or energy have devoted part of their revenues to the reduction of other distortionary taxes (green tax reforms), although other revenue uses are now playing an increasing role (Ekins and Speck, 2011).

Border tax adjustments are related instruments that intend to solve the dysfunctions of variable climate change regulations across the world. Although some authors highlight that they could alleviate the problem of leakage and a contribute to a wider application of climate change mitigation policies (Ismer and Neuhoff, 2007), others emphasize that they do not constitute optimal policy instruments and could even increase leakage (Jakob et al., 2013) or cause potential threats to fairness and to the functioning of the global trade system (e.g. Bhagwati and Mavroidis (2007)).

Subsidies to low GHG products or technologies have been applied by a number of countries but, contrary to the previous revenue-raising/neutral economic instruments, they demand public funds. In some countries there are "perverse" subsidies lowering the prices of fossil fuels or road transport, which bring about a higher use of energy and an increase of GHG emissions. Therefore, *subsidy reduction or removal* would have positive effects in climate change and public-revenue terms and is therefore treated as an instrument in its own right (OECD, 2008).

In 'cap and trade' *emission trading systems* regulators establish an overall target of emissions and issue an equivalent number of emissions permits. Permits are subsequently allocated among polluters and trade leads to a market price. The allocation of emission permits can be done through free distribution (e.g. grandfathering) or through auctioning. In 'baseline and credit' emission trading systems, polluters may create emission reduction credits (often project-based) by emitting below a baseline level of emissions (Stavins, 2003).

15.3.2 Regulations and Standards

Regulations and standards were the core of the first environmental policies and are still very important in environmental and climate policies all around the world. They are conventional regulatory approaches that establish a rule and/or objective that must be fulfilled by the polluters who would face a penalty in case of non-compliance with the norm. There are several categories of standards that are applicable to climate change policies, mainly:

Emission standards are the maximum allowable discharges of pollutants into the environment, and can also be termed as performance standards

Technology standards that mandate specific pollution abatement technologies or production methods (IPCC, 2007)

Product standards that define the characteristics of potentially polluting products (Gabel, 2000).

15.3.3 Information Policies

A typical market failure in the environmental domain is the lack or at least asymmetric nature of relevant information among some firms and consumers. Good quality information is essential for raising public awareness and concern about climate change, identifying environmental challenges, better designing and monitoring the impacts of environmental policies, and providing relevant information to inform consumption and production decisions. Examples of information instruments include eco-labelling or certification schemes for products or technologies and collection and disclosure of data on GHG emissions by significant polluters (Krarup and Russell, 2005).

15.3.4 Government Provision of Public Goods and Services and Procurement

A changing climate will typically be a "Public Bad" and actions and programs by governments to counteract or prevent climate change can thus be seen as Public Goods. There are many examples where Public Good provision may be an appropriate form of climate mitigation or adaptation. Examples include physical and infrastructure planning, provision of district heating or public transportation services(Grazi and van den Bergh, 2008), and funding and provision of research activities (Metz, 2010). Moreover, the removal of institutional and legal barriers that promote GHG emissions (or preclude mitigation) should be included in this policy type. Afforestation programs and conservation of state-owned forests are an important example.

15.3.5 Voluntary Actions

Voluntary actions refer to actions taken by firms, NGOs and other actors beyond regulatory requirement. Voluntary agreements represent an evolution from traditional mandatory approaches based on conventional or economic regulations and intend to provide further flexibility to polluters. They are based on the idea that, under certain conditions, polluters can decide collectively to commit themselves to abatement instead of, or beyond the requirements of regulation. Voluntary agreements, sometimes known as long-term agreements, can be developed in different ways: in most cases the voluntary commitment is assumed as a consequence of an explicit negotiation process between the regulator and the pollutant. In other cases a spontaneous commitment may be viewed as a way to avoid future mandatory alternatives from the regulator (Metz, 2010). Finally, there are cases where the regulator promotes standard environmental agreements on the basis of estimation of costs and benefits to firms (Croci, 2005).

15.4 Approaches and tools used to evaluate policies and institutions

15.4.1 Evaluation Criteria

Several criteria have been usually employed to assess the effects of climate change policies and these have been laid out in Chapter 3. The criteria that have been used are environmental effectiveness, economic effectiveness (cost-effectiveness and economic efficiency), distributional equity and broader social impacts, and institutional, political, and administrative feasibility and flexibility. Political and institutional feasibility are not only a separate criterion but also need to be taken into account when judging other criteria such as economic effectiveness. It would be misleading to show that a tax would have been more cost-effective than e.g. a regulation if it would never have been feasible to implement the tax at a sufficiently high level to have the same effect as that regulation.

15.4.2 Approaches to Evaluation

One can evaluate the effect of policy instrument *x* on a set of variables *y* that matter for the evaluation criteria either through modelling or through ex-post empirical measurement. For any evaluation based solely on modelling, it will never be possible to know whether all important aspects of the relationship between *x* and the *y's* are captured appropriately by the model. For this reason, it is highly desirable to have ex-post empirical analysis to evaluate a policy instrument. In order to measure the effect of a policy instrument, one must compare the observed *y's* in the presence of *x* with the "but-for" or "counterfactual" value of the *y's*—defined as their estimated likely value but for the implementation of x.

Statistical methods can be used to attempt to control for the evolution of the world in the absence of the policy. The most reliable basis for estimating counterfactual developments is to build program evaluation into the design of programs from their inception (Jaffe, 2002). If the planning of such evaluation is undertaken at the beginning of a program, then data can be developed and maintained that greatly increase the power of statistical methods to quantify the true impact of a program by controlling for but-for developments.

Statistical analyses capture only those policy effects that can be and have been measured quantitatively. Qualitative analyses and case studies complement statistical analyses by capturing the effects of policies and institutions on other aspects of the system, and the effect of institutional, social and political factors on policy success (e.g., Bailey et al (2012)).

Of course, data for ex-post evaluation is not always available, and even where it is, it is frequently impossible to capture all aspects of the situation empirically. Therefore, there will always be a role for models to elucidate the structure of policy effects, and to estimate or put bounds on the magnitude of effects. Such models can be purely analytical/theoretical, or they can combine empirical estimates of certain parameters with a model structure, as in "bottom-up" models where many small effects are estimated and cumulated, or in simulation models, which combine an analytical/theoretical structure with numerical estimates of parameters of the model. Many such models are "partial equilibrium," meaning they capture the particular context of interest but ignore impacts on and feedback from the larger system. There are also computable "general equilibrium" (CGE) models that allow for interactions between the context of the policy focus and the larger system, including overall macroeconomic impacts and feedbacks see for e.g. (Bohringer et al., 2006).

"Experimental economics" uses a laboratory setting as a "model" of a real-world process, and uses experimental subjects' responses in that setting as an indicator of likely real-world behaviour (Kotani et al., 2011). With any model, results are truly predictive of real-world results only to the extent that the model—be it theoretical, simulation or experimental—captures adequately the key aspects of the real world in the experiment.

15.5 Assessment of the Performance of Policies and Measures, including their policy design, in developed and developing countries taking into account development level and capacity

15.5.1 Introduction

In this section we assess the performance of a series of policy instruments and measures, starting with economic instruments (taxes in 15.5.2, emissions trading in 15.5.3), regulatory approaches (15.5.4), information programs (15.5.5), government provision of public goods (15.5.6) and voluntary agreements (15.5.7). We go on to assess aspects of these and other policies in Section 15.6 on technology and R&D policy, and in Section 15.7 that deals with interactions between policies.

Many policy instruments are in principle capable of covering the entire economy. However, as mentioned in 15.2, in practice the instruments are often targeted to particular sectors or industries. This partly reflects the fact that certain barrier or market failures are specific to or more pronounced in certain sectors or industries. Furthermore, some policies may cover only part of the economy as a result of the ability of special interests to exempt some sectors or industries (Compston, 2009), (Helm, 2010).

Broader coverage tends to promote greater cost-effectiveness. However, on fairness grounds there is an argument for partly or fully exempting certain industries in order to maintain international competitiveness, particularly when the threat to competitiveness comes from other nations that have not introduced climate policy and would gain competitive advantage as a result.

Table 15.2 brings together policy instruments discussed in sector chapters (Chapters 7 to 12). Two broad themes emerge from this survey. First, while policies that target broad energy prices – taxes or tradable allowances are clearly applicable across all sectors, a wide range of other policy approaches are also prevalent, which enable policy design that addresses sector specific attributes. For example, in the buildings sector regulatory instruments are an important tool, as in the absence of a building code enforcing enhanced efficiency, an energy price signal alone might be insufficient to induce a builder to invest in an energy efficient building that she plans to sell or rent. Building and product standards also increase investor certainty thereby reducing costs. Similarly, the transport sector relies not only on pricing policies but also on government provision of infrastructure and regulation that guides urban development and modal choices. The industry sector faces information and other barriers to investment in efficiency, which can be overcome by audits and other information based programmes. In AFOLU, government regulation to protect forests and set the conditions for REDD+ plays a substantial role, as do certification programmes for sustainable forestry.

Sector-specific policies often exist alongside broader ones. In energy supply, broad-based GHG emissions pricing has often been supplemented by specific price- and quantity-based mechanisms (such as feed-in-tariffs and portfolio standards) and underpinned by sufficient regulatory stability (including non-discriminatory access to electricity and gas networks). In industry, relatively broad tax exemptions may be combined with mandatory audits, with the former helping "level the playing field" and providing the impetus for action, and the latter addressing an information barrier; thus each instrument addresses a separate market failure or barrier. The implementation of multiple policy instruments within a single sector can promote cost-effectiveness when the two instruments address distinct market failures. On the other hand, multiple instruments can work against cost-effectiveness when the two instruments fail to address different market failures and thus are simply redundant. This issue is discussed further in Section 15.7 below.

Table 15.2: Sector Policy Instruments

Policy Instruments	Energy (See 7.12)	Transport (See 8.10)	Buildings (See 9.10)	Industry (See 10.11)	AFOLU (See 11.10)	Human Settlements and Infrastructure
Economic Instruments – Taxes (Carbon taxes may be economy-wide)	- Carbon taxes	- Fuel taxes - Congestion charges, vehicle registration fees, road tolls - Vehicle taxes	- Carbon and/or energy taxes (either sectoral or economy wide)	- Carbon tax or energy tax - Waste disposal taxes or charges	- Fertilizer or Nitrogen taxes to reduce nitrous oxide	- Sprawl taxes, Impact fees, exactions, split-rate property taxes, tax increment finance, betterment taxes, congestion charges
Economic Instruments – Tradable Allowances (May be economy-wide)	- Emission trading (e.g. EU ETS) - Emission credits under CDM - Tradable Green Certificates	-Fuel and vehicle standards	- Tradable certificates for energy efficiency improvements (white certificates)	- Emission trading - Emission credit under CDM - Tradable Green Certificates	- Emission credits under CDM (Adam) - Compliance schemes outside Kyoto protocol (national schemes) - Voluntary carbon markets	- Urban-scale Cap-and-Trade
Economic Instruments – Subsidies	- Fossil fuel subsidy removal - Feed in tariffs for renewable energy - Capital subsidies and insurance for 1st generation CCS	- Biofuel subsidies - Vehicle purchase subsidies - Feebates	- Subsidies or Tax exemptions for investment in efficient buildings, retrofits and products - Subsidized loans	- Subsidies (e.g. for energy audits) - Fiscal incentives (e.g. for fuel switching)	- Credit lines for low carbon agriculture, sustainable forestry.	- Special Improvement or Redevelopment Districts

Regulatory Approaches	- Efficiency or environmental performance standards - Renewable Portfolio standards for renewable energy - Equitable access to electricity grid - Legal status of long term CO2 storage	- Fuel economy performance standards - Fuel quality standards - GHG emission performance standards - Regulatory restrictions to encourage modal shifts (road to rail) - Restriction on use of vehicles in certain areas - Environmental capacity constraints on airports - Urban planning and zoning restrictions	- Building codes and standards - Equipment and appliance standards - Mandates for energy retailers to assist customers invest in energy efficiency	- Energy efficiency standards for equipment - Energy management systems (also voluntary) - Voluntary agreements (where bound by regulation) - Labelling and public procurement regulations	- National policies to support REDD+ including monitoring, reporting and verification - Forest law to reduce deforestation - Air and water pollution control GHG precursors - Land-use planning and governance	- Mixed use zoning - Development restrictions - Affordable housing mandates - Site access controls - Transfer development rights - Design codes - Building codes - Street codes - Design standards
Information Programmes		- Fuel labelling - Vehicle efficiency labelling	- Energy audits - Labelling programmes - Energy advice programmes	- Energy audits - Benchmarking - Brokerage for industrial cooperation	-Certification schemes for sustainable forest practices - Information policies to	

					support REDD+ including monitoring, reporting and verification	
Government Provision of Public Goods or Services	- Research and development - Infrastructure expansion (district heating/cooling or common carrier)	- Investment in transit and human powered transport - Investment in alternative fuel infrastructure - Low emission vehicle procurement	- Public procurement of efficient buildings and appliances	- Training and education - Brokerage for industrial cooperation	- Protection of national, state, and local forests. Investment in improvement and - Diffusion of innovative technologies in agriculture and forestry	-Provision of utility infrastructure such as electricity distribution, district heating/cooling and wastewater connections, etc. - Park improvements - Trail improvements -Urban rail,
Voluntary Actions			- Labelling programmes for efficient buildings - Product eco-labeling	- Voluntary agreements on energy targets or adoption of energy management systems , or resource efficiency	- Promotion of sustainability by developing standards and educational campaigns	

15.5.2 Taxes, Charges, and Subsidy Removal

15.5.2.1 Overview

Taxes on carbon (together with emission trading systems) are economic instruments. In the presence of rational consumers, firms and complete markets, they achieve any given level of emissions reduction in the least costly way possible. Economic instruments like carbon taxes are attractive because of their simplicity and broad scope - covering all technologies and fuels (Section 3.8) and thus evoking the cost-minimising combination of changes to inputs in production and technologies to changing behaviour as manifested in consumption choices and lifestyles. This is the reason they have the potential to be more efficient than directly regulating technology, products or behaviour.[2]. To minimize administrative costs, a carbon tax can be levied "upstream" (at the points of production or entry into the country). Finally, unlike an emission trading system that requires new administrative machinery, a tax can piggyback off existing revenue collection systems.

Despite these attractive properties, carbon taxes are not nearly as prevalent a policy instrument as one might expect. As yet, the Scandinavian countries, the Netherlands, the UK, and the Canadian province of British Columbia are the only large jurisdictions with significant and fairly general carbon taxes of at least $10/tCO2.[3] The reasons for this are not entirely clear. It may be that a carbon tax, unlike a narrower sectoral regulation, attracts more hostile lobbying from fossil fuel interests[4] for whom the stakes it creates are high (Hunter and Nelson, 1989; Potters and Sloof, 1996; Goel and Nelson, 1999; Godal and Holtsmark, 2001; Skjærseth and Skodvin, 2001; Kolk and Levy, 2002; van den Hove et al., 2002b; McCright and Dunlap, 2003; Markussen and Svendsen, 2005; Pearce, 2006; Beuermann and Santarius, 2006; Deroubaix and Lévèque, 2006; Pinkse and Kolk, 2007; Bridgman et al., 2007; Bjertnæs and Fæhn, 2008; Blackman et al., 2010; Sterner and Coria, 2012). Secondly, the payments required by a tax are transparent, unlike the less visible costs of regulations. The general public, not being aware of the above-mentioned efficiency properties of a tax, may be less likely to accept such an instrument (Brännlund and Persson, 2010). Third, policy may be driven by perceived risks to competitiveness and employment as well as the distribution of costs rather than on considerations of pure efficiency (Decker and Wohar, 2007). Finally, a set of institutional path dependencies may have led to a favouring of emissions trading systems over taxes, including a post-Kyoto preference for emissions trading in key bureaucracies, supported by creation of supportive industry and other associations (Skjærseth and Wettestad, 2008; Paterson, 2012).

Countries that have sizeable general carbon taxes are fewer still – mainly a few Northern European countries. The carbon tax in Sweden is 1100 SEK or 165 USD/ton, which is an order of magnitude higher than the price of permits on the EU ETS market or than the carbon taxes discussed in many other countries. Such high taxes typically have some exemptions motivated by the fact that other (competing) countries have no (or low) taxes. Sweden, for example, exempted the large energy users who participate in the EU ETS from also paying the carbon tax on the ground that there would otherwise be a form of "double" taxation (See 15.5.2.4 for a more thorough discussion).

Although general carbon taxes are so far uncommon, there are many policies that partly have similar effects but (for political reasons) avoid using the words "carbon" and/or "tax", (Rabe and Borick, 2012). Taxes on fuels, especially transport fuels are very common. While narrower in scope, they

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[2] If psychological or institutional barriers to adoption or other market failures are the main factor impeding choice then regulations or other instruments may be an efficient complement or stand-alone instrument to deal with this (15.4).

[3] Australia has a fixed fee hybrid system sometimes described as a tax that will be converted into an ETS.

[4] These can be either producers (for instance of fossil fuels) or users of energy, ranging from energy intensive industries to truck drivers.

nevertheless cover a significant fraction of emissions in many countries. These can be interpreted as sectoral carbon taxes; in some countries this is clearly stated as an objective of fuel taxes, in others it is not. They may be politically easier to implement in some countries since (private) transport is hardly subject to international competition and hence leakage rates are low. A large share of all revenues from environmentally related taxes in fact come from fuel taxes which were introduced in various countries, beginning with Europe and Japan, though they are also common in low income, oil-importing countries. One of their main stated purposes is to finance road building, although additional arguments include reducing expensive imports, government revenue raising, and reducing environmental impacts. Irrespective of the motivation, the effect of carbon taxes on fuel is to raise prices to consumers and restrict demand, see next section. This is important since the transport sector represents a big and increasing share of carbon emissions (27% of global energy-related CO2 emissions in 2010 - see 8.1). Theory, simulation and empirical studies suggest strongly that taxing fuel is a lower cost method of reducing emissions compared to policies such as fuel efficiency mandates, driving restrictions, or subsidies to new technologies[5] (Austin and Dinan, 2005). However, consumers who buy vehicles may be unable to correctly internalize the long-run savings of more fuel-efficient vehicles. This would be “a barrier” and provide motivation for having fuel efficiency standards in addition to fuel taxes (see 15.5.4).

Variation in fuel prices is generated by subsidies as well as taxes. Fossil fuel subsidies are prevalent in many countries, being most common in oil and coal producing countries. According to the IMF (2013), the Middle East and North Africa region accounts for around 50% of global energy subsidies. In 2008, fossil fuel subsidies – for transport fuels, electricity, tax breaks for oil and gas production, and for research and development into coal generation exceeded $500 billion globally (IEA/OECD, 2011). A more recent estimate by the IMF (2013) puts the figure at $480 billion or 0.7% of global GDP in 2011. This is a pre-tax estimate and includes petroleum products, electricity, natural gas, and coal. A large share is in the fossil fuel exporting countries. After factoring in negative externalities, through corrective taxes, the IMF reports $1.9 trillion in implicit subsidies. This figure assumes damages corresponding to a $25 per ton social cost on carbon, consistent with United States Interagency Working Group on Social Cost of Carbon (2010). “Advanced economies” make up 40% of the global post-tax estimate. Reviewing six major studies that estimate fossil fuel subsidies, Ellis (2010) notes that removal of such subsidies would increase the aggregate GDP in OECD and non-OECD countries in the “range from 0.1 per cent in total by 2010 to 0.7 per cent per year to 2050 (Ellis, 2010).” The studies reviewed include both modeling and empirical exercises.

15.5.2.2 Environmental effectiveness and efficiency

Assessing the environmental effectiveness of carbon taxation is not straightforward because multiple instruments and many other factors co-evolve in each country to produce policy mixes with different outcomes in terms of emissions. For example, energy taxes varying by sector have been prominent in the Nordic countries since the 1970’s with carbon taxes being added on in the early 1990’s. Ex-post analyses have found varying reductions in CO2 emission from carbon taxes in Norway, Sweden, Denmark, and Iceland, compared to business-as-usual (see (Andersen, 2004) for an extensive review of these studies and their estimation techniques).

The UK’s Climate Change Levy (CCL), introduced in 2001 on manufacturing plants and non-residential energy users (offices, supermarkets, public buildings, etc.), has had a strong impact on energy intensity (Martin et al., 2011). Electricity use, taxed at a rate of about 10%, declined by over 22% at plants subject to the levy as compared to plants that were eligible to opt out by entering into a voluntary agreement to reduce energy use. There was no evidence that the tax had any detrimental effect on economic performance or led plants to exit from the industry (Martin et al., 2011).

[5] See also section 15.12 on climate finance.

During 1990 to 2007, the CO2 equivalent emissions in Sweden were reduced by 9% while the country experienced an economic growth of +51%. In Sweden, with the highest carbon tax (albeit with exemptions for some industrial sectors), there was a very strong decoupling of carbon emissions and growth with reductions in carbon intensity of GDP of 40%. (OECD, 2000; Hammar et al., 2013). Per capita emissions in Denmark were reduced by 15% from 1990 to 2005; The experience in Scandinavia, the UK and the Netherlands was similar (Enevoldsen, 2005; Enevoldsen et al., 2007), (Bruvoll and Larsen, 2004)), (Cambridge Econometrics, 2005), (Berkhout et al., 2004; Sumner et al., 2011a; Lin and Li, 2011). Of course, many factors may be at play, and these differences cannot be attributed solely to differences in taxation. Overall, the evidence does suggest that carbon taxes, as part of an environmental tax reform, lead to abatement of greenhouse gas emissions, generate revenue for the government, and allow reductions in income tax threatening employment. Theory strongly suggests that if a tax is implemented then it would also be cost effective but it is for natural reasons hard to demonstrate this empirically at the macro level. .

There is much more evidence available on the environmental efficacy of fuel as compared to carbon taxation. In the short run, consumers may be locked into patterns of use by habit, culture, vehicle characteristics, urban infrastructure and architecture. The short-run response to higher fuel prices is indeed often small – price elasticity estimates range between -0.1 to -0.25 for the first year. However long-run price elasticities are quite high: approximately -0.7 or a range of -0.6 to -0.8 (this is the average found by surveys of hundreds of studies that use both market based variations in fuel price as well as policy induced variations and exploit both temporal and cross-sectional variations in the data (the individual study estimates range substantially more depending on countries or regions covered, time period, method and other factors) (Oum, 1989; Goodwin, 1992; Graham and Glaister, 2002; Goodwin et al., 2004). This means that in the long run, 10% higher fuel prices will ultimately lead to roughly a 7% reduction in fuel use and emissions. Income elasticities are about 1 which means that 5% growth in income gives 5% growth in emissions. If instead a 2% reduction is desired there is a 7% gap between the 5% increase and the -2% desired and a 10% increase in fuel price every year would be needed to achieve such a reduction in emissions with a 5% growth in income.

The long-run effects of transport fuel taxation have been large: the whole OECD would have had 30% higher fuel use had not the EU and some other members imposed high fuel taxes (i.e., if all the OECD countries had instead chosen as low fuel taxes as in the US). Similarly, the OECD could have decreased fuel use by more than 35% if all member countries would have chosen as high taxes as the UK. The accumulated difference in emissions over the years leads to a difference in several ppm in CO2 concentration, presumably making fuel taxes the policy that has had the largest actual impact on the climate up till now (Sterner, 2007).

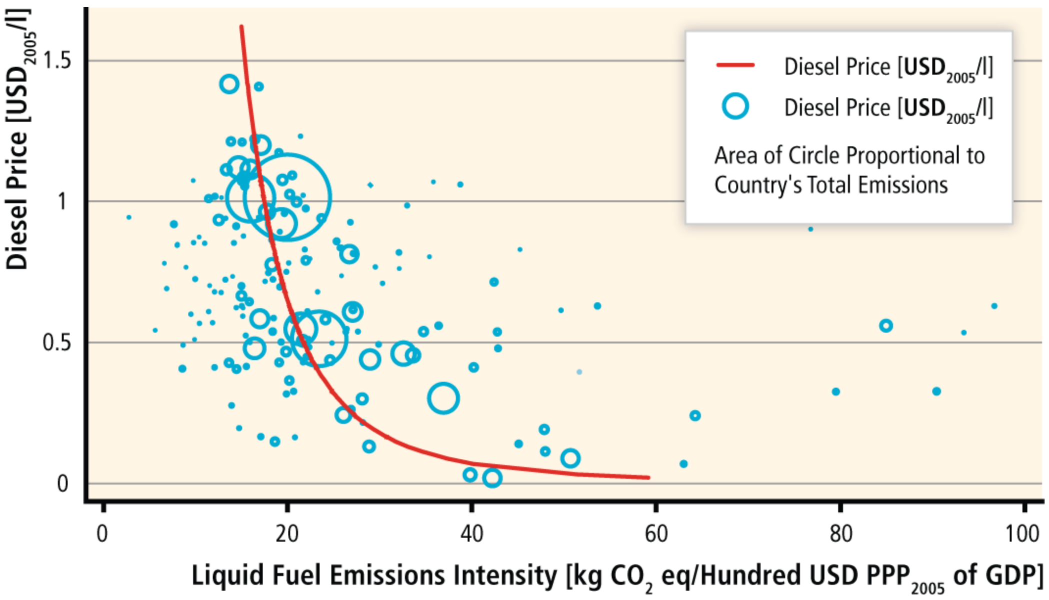

Figure 15.2 The impact of average diesel prices across the world on the emissions intensity of liquid fuels.

The environmental effect of a fuel tax is illustrated in Figure 15.2 where the fitted curve is from a log-linear regression of the emission intensity of liquid fuels on the price of diesel. The cross-country variation in diesel prices is mostly due to variation in taxes (and in some cases, subsidies). Figure 15.2 suggests that the effect of a change in the price of a fuel on emissions is greater at low prices. This is intuitive, since fuel will be consumed wastefully when it is cheap, allowing for greater demand reductions when the price rises.

Though there are few clean experiments, the market continuously creates “quasi-experiments” which are analogous to the introduction of policies. Increased fuel prices in the USA in 2008, for instance, led to a shift in the composition of vehicles sold increasing fuel-efficiency, while also reducing miles travelled (Ramey and Vine, 2010; Aldy and Stavins, 2012).

Other price instruments that have been used in the transport sector are congestion charges, area pricing, parking fees, and tolls on roads or in cities. These have been used to reduce congestion; emission reduction is a co-benefit. The £10 congestion fee in London led to reductions in incoming private cars by 34% when introduced. Overall congestion was also estimated to have been reduced by 30%, and emissions fell (Leape, 2006). The smaller (2€) congestion fee in Stockholm reduced total road usage by 15% (Johansson et al., 2009).

Reducing subsidies to fossil energy will have a significant impact on emissions. Removing them could reduce world Greenhouse Gases (GHG) emissions by 10% at negative social cost (Burniaux and Chateau, 2011)(Burniaux and Chateau, 2011).The IMF calculates that the removal of these subsidies induce a 15% reduction in global energy related carbon emissions or 5 billion tons in absolute terms and concludes that the post-tax estimate of $1.9 trillion in subsidies is “likely to underestimate” energy subsidies due to the assumptions made, hence the impact on carbon emissions is likely to be higher. Ellis (2010) reports a range of effects from just a few percent to 18% depending on the size of the subsidy reduction.

Recognizing this, the G20 and APEC blocks agreed in 2009 to phase out inefficient fossil fuel subsidies in all countries (G20 Leaders, 2009).

In China, the energy saving policies adopted in 1991, the 1998 Law on Energy Conservation, and the 2004 Medium and Long Term Specific Schema on Energy Saving, led to higher energy prices and explain half the decline in energy intensity of Chinese industries between 1997 and 1999, while R&D accounted for only 17% of the decline (Fisher-Vanden et al., 2006; Yuan et al., 2009).

15.5.2.3 Distributional Incidence and feasibility

Although fuel taxes have often been criticized for being regressive (that is, for imposing a proportionally higher burden on the poor), this is not always the case. There are large variations in distributional impacts both within and between social groups, and but the effects range from regressive or progressive (Rausch et al., 2010, 2011); see also 6.3.5.2.

Studies of the distributional incidence of fuel taxes show that they may be neutral or weakly regressive (before revenue recycling) in rich countries, but they are generally progressive in poor countries. In many least developed and developing countries such as India, Indonesia, China, and many African countries, the progressivity of fuel taxes is in fact quite strong. In Europe they are approximately neutral (Sterner, 2012). Carbon taxation can sometimes have regressive effects prior to recycling revenue, but recycling can make the poorest households better off. Generally the degree of progressivity can be selected depending on the method of recycling revenues. The environmental taxation gives rise to government income that can be allocated in ways that either benefit the poor or any other group giving a considerable range of options for how progressive or regressive the politicians want to make the overall package, (Bureau, 2011).

The distributional effects of other taxes vary significantly. Kerosene taxes in developing countries are regressive since kerosene is used predominantly by the poor (Younger et al., 1999; Gangopadhyay et al., 2005; Datta, 2010). This may also apply to taxes on electricity or coal. The distributional effects of a more general carbon tax will depend on the mode of implementation with respect to different fuels and sectors and typically be more complex than for a single fuel since the potential substitution possibilities are many. Results vary but for instance Hassett et al. (2009), finds a carbon tax to be regressive in the USA showing that the cost is about 3.74% for the poorest decile - four times the effect on the highest decile. In India, on the other hand, a carbon tax would be progressive (Datta, 2010). The pro- or re-gressivity of carbon taxes will vary between countries but can also be affected by design as shown for instance by Fullerton et al (2012) or Sterner and Coria (2012).

The assertion that fuel taxes are regressive is often used as an argument and can make fuel taxes politically difficult to implement even if not true. Feasibility is however not tied in any simple way to income distribution effects. If a tax is progressive, this does not necessarily increase feasibility since this means that the interests of influential groups are affected which may be a much bigger impediment to feasibility, (Datta, 2010). Fear of social unrest may hold up subsidy removal. Protests over reduced petrol subsidies are common; recently riots erupted in Nigeria when President Jonathan Goodluck tried to eliminate very costly petrol subsidies with only partial success. Some countries such as Iran and Indonesia have recognized that fuel subsidies actually accrue to the relatively wealthy and managed to successfully reduce them without much unrest, by making sure that revenues saved are spent fairly – for instance through general lump-sum cash transfers (Coady et al., 2010; Atashbar, 2012; Sterner, 2012; Aldy and Stavins, 2012).

15.5.2.4 Design Issues: Exemptions, revenue recycling, border adjustments

As mentioned above in 15.5.2.1, despite the attractive efficiency properties of a broad carbon tax, and even its progressivity in many circumstances, it may face political resistance. To have a big effect on emissions a tax must however be high. Carbon and fuel taxes have often been initially resisted but once introduced it seems the fee level has often been increased, (Sumner et al., 2011b). Another may be a path dependency since the taxes reduce the use of fossil fuel and lower fuel use means less opposition to fuel taxes, (Hammar et al., 2004). This may be the rationale for raising the fuel or carbon taxes slowly and steadily as done by the Conservative government in the UK with the Fuel Price Escalator starting in 1993, a policy that was continued under the successor Labour government for several years.

An emissions tax involves a transfer from economic agents to the state, namely the tax revenue from the residual emissions that are not abated. Private parties have to make this transfer in addition to bearing the cost of actually reducing emissions. There are a number of approaches to designing a tax (or fee) so that the transfer does not take place and resistance from incumbent polluters is reduced.

One approach that has been taken is simply to exempt certain carbon-intensive industries – such as heavy industry in Sweden as mentioned earlier. Such policies with incomplete coverage are less cost efficient than general policies (Montgomery, 1972) and chapter 6.3.5.1). This applies not only to carbon emissions – it applies even more broadly to agriculture, forestry and to other climate gases such as methane or nitrous oxide (Bosetti et al., 2011). However, narrow sectoral policies may be politically more feasible, due to concerns about international competitiveness, the structure of winners and losers, and consequent lobbying (Holland et al., 2011).

A related approach that tries to avoid the loss of coverage is to exempt some firms from taxes conditional on their undertaking emission reduction commitments. In Denmark, companies signing an energy savings agreement with the government received a 25% tax reduction (OECD, 2001; Agnolucci, 2009; Sumner et al., 2011a; Ekins and Speck, 2011; Aldy and Stavins, 2012). Similarly in the UK some firms may sign Climate Change Agreements to reduce emissions that exempt them from the Climate Change Levy. This experience offers a cautionary tale: on average the agreements did not require firms to reduce emissions beyond what they would have done anyway (Martin et al., 2011). Conditional exemptions amount to unconditional ones if the conditions are lax.

Another approach to avoiding a large transfer to the state is to recycle all or part of the tax revenue. In the Canadian province of British Columbia, revenue from the broad carbon tax of $30/tCO2 is fully rebated to the general population via income tax cuts and transfers to low-income people who do not pay income tax. British Columbia raised the tax gradually in increments of $5/tCO2 annually to its current level (Jaccard, 2012).

Sometimes revenues are recycled to firms in emission-intensive industries. Again, this relies on identifying the recipients so it is usually confined to a few sectors with the attendant disadvantages mentioned above. Refunded emission payments and other combinations of taxes and subsidies may be designed to be neutral so that, for example, the industry pays the cost of abatement but does not pay a tax for the allowed or reference level of pollution (Fischer, 2011). One expression of this is fees, which are collected in environmental funds and subsequently used in ways that benefit the polluters. An example from NOx emissions in Sweden is that a refunded emission payment may be politically more acceptable and thus environmentally more effective than simply a tax. Since the fee is refunded (in proportion to output), there is considerably less resistance to the fee and it can be set much higher than what would have been acceptable for a pure tax. Norway has pioneered another instrument for NOx emissions –taxes are refunded to cover abatement expenses. This implies a combination of a tax on emissions with a subsidy on abatement. Experience shows that a lower fee can achieve the same result with this instrument design as a tax (Fischer, 2011). Norway is considering promoting similar solutions for carbon emissions (Hagem et al., 2012). The drawback of such schemes for reducing carbon emissions is that their sectoral nature reduces coverage and raises costs.

Abatement subsidies have also been financed out of general revenues. Abatement subsidies need to be financed through tax revenues. The taxes needed to finance the subsidies in general involve a marginal excess burden. This deadweight loss is an extra cost of subsidies relative to emissions taxes. Furthermore there is an efficiency penalty due to their sectoral nature. If applied to firms, they may create perverse incentives to enter or to fail to exit from, a polluting industry, and raise costs (Polinsky, 1979). Perhaps for such reasons, they are seen in residential and commercial sectors, for instance, tax breaks are provided for building insulation or refurbishing. There are also white certificates and innovative financing schemes that allow loans to be repaid as part of electricity bills (see 9.10 for further discussion).

Another reason for tax exemptions is to avoid a loss of competitiveness in industries exposed to foreign competition that is not subject to taxation or equivalent policies. A pure tax (at a high level) may incentivize industries to move to neighbouring countries. This is known as leakage, since emissions `leak' to jurisdictions not subject to taxation. It is generally hard to find decisive empirical evidence of carbon leakage, though this may be partly because high carbon taxes have not been tried in any significant way for trade-exposed sectors. As discussed in Chapter 5, some simulations suggest that there could be sizeable effects (Elliott et al., 2010). Though the overall effects of border tax adjustment on leakage are subject to debate (see Jakob et al. (2013)), a recent model comparison suggests that full border tax adjustments would moderately decrease leakage rates from on average from on average 12 to 8% (Bohringer et al., 2012). Border tax adjustments are taxes levied on imported goods that impose equivalent taxes on emissions `embedded' in the goods. (Aichele and Felbermayr, 2011) find that sectoral carbon imports for a committed (i.e. taxed) country from an uncommitted exporter are approximately 8% higher than if the country had no commitments and that the carbon intensity of those imports is about 3% higher. When measurement of embedded emissions is uncertain, border tax adjustments can be criticized for introducing trade barriers in environmental guise (Holmes et al., 2011).

Leakage can also occur intertemporally. As shown by Sinn (2008, 2012) a carbon tax might not only encourage demand in other areas. There may also be a perverse supply side reaction (referred to as the Green Paradox) increasing the current supply of fossil fuels in anticipation of rising carbon taxes. Subsequent research (Gerlagh, 2011; Hoel, 2012) has shown that this strictly speaking only applies to very simplified and special models with complete exhaustion of all fossil fuels (which would lead to very drastic climate change) and also only to models in which the carbon tax actually starts low and rises faster than the discount rate. A number of conclusions can be drawn from the debate: Generally, the supply side should not be neglected. If a tax is used there are arguments for making it high rather than low and fast-growing, and most importantly, instruments used need to cover as many countries and sources as possible. It may be difficult to find a single optimal tax and it may be necessary rather to formulate a tax rule that will decide how the tax rate is to be updated, (Kalkuhl and Edenhofer, 2013).

15.5.3 Emissions Trading

15.5.3.1 Introduction

Over the past three decades, emissions trading or cap-and-trade has evolved from just a textbook idea (Dales, 1968) to its current role as a major policy instrument for pollution control. Earlier experiences with emissions trading include schemes such as the California RECLAIM program and the US Acid Rain program (Tietenberg, 2006; Ellerman, Convery, and De Perthuis, 2010).

But since the start of the EU carbon trading system –see 14.4.2--, several countries and subnational jurisdictions (e.g., New Zealand, Australia, California, northeastern United States, Quebec, South Korea, Tokyo, and 5 cities and 7 provinces in China) have also put in place or proposed trading schemes to control their carbon emissions. This section provides a brief overview of the literature (see further (Perdan and Azapagic, 2011; Aldy and Stavins, 2012) and draws lessons for the design of carbon trading programs.

15.5.3.2 Has emissions trading worked?

We begin by assessing environmental effectiveness. There were three GHG cap-and-trade programs that were operational[6] by 2012 (Newell et al 2013). The EU ETS, reviewed in 14.4.2, is by far the

[6] California and Quebec started recently in 2013 as did Australia with its "fixed-price" or tax period; Trading starts 2014 and S Korea starts even later. None of these can be evaluated empirically at present.

largest. Emissions are estimated to have fallen by 2-5% relative to business as usual in the first pilot phase from 2005-2007 (Ellerman, Convery, De Perthuis, et al., 2010).Similarly, Egenhofer et al (2011) attribute reduction of emission intensity by 3.35% per year in 2008-2009, in contrast to only 1% in 2006-2007, to the EU ETS. Permit prices have fallen to around $10-15 in 2012 (Newell et al., 2013). Section 14.4.2 concludes that environmental effectiveness has been compromised to a large extent by a structurally lenient allocation of permits that was driven by the necessity for institutional and political feasibility.

The Regional Greenhouse Gas Initiative (RGGI), (see 15.5.3.3) has been ineffective since the cap has never been binding and is not expected to become so for several years (Aldy and Stavins, 2012). The third, much smaller, New Zealand ETS, appears to have had a small impact on emissions (Bullock, 2012). The last of the emission trading schemes in GHGs, the Clean Development Mechanism, (CDM) was an offset program, not a cap-and-trade scheme. Section 13.13.1.2 finds that there are many challenges when it comes to additionality, baseline definition and leakage but possibly some advantages from the viewpoint of generating income in developing countries.

This experience shows that it is has been very difficult to get a cap-and-trade program for GHGs enacted with a cap tight enough to have a significant environmental effect, at least initially. Other programs (notably for the whole USA) that have been suggested have not made it through the political process. It is unclear to what extent this issue is peculiar to ETSs but there is a similar if not stronger opposition to the other major economic instrument, carbon taxation. One of the advantages claimed for an ETS is a greater option of allocating rights to appease opponents of a tax scheme. Hence there is a trade-off between feasibility, distributional effects and environmental effectiveness at least in the short run. Older non-GHG cap-and-trade programs such as the SO2 and leaded petrol phase-out programs in the US have been environmentally effective (Tietenberg, 2006; Schmalensee and Stavins, 2013).[7] It may be that any policy instrument stringent enough to have a significant environmental effective program may have faced opposition in the particular circumstances. One possible lesson for design may be to build a price ceiling into any proposed cap-and-trade program. In that case, the concern that a tight cap would lead to very high costs, would be alleviated and may make it politically feasible to have a somewhat more ambitious cap (Aldy and Stavins, 2012).

Cost-effectiveness is the main economic rationale for using emission trading as opposed to simpler regulation. The experience with regard to GHG programs is too limited to draw any conclusions yet. As in many of the earlier markets, cost savings in the US Acid Rain program ---an allowance trading system established in 1995 to control SO2 emissions from coal-fired plants in the continental US--- were substantial (e.g., (Carlson et al., 2000; Ellerman et al., 2000). Cost savings in this program came not only from equalizing marginal costs across affected electric utility units on a period-by-period basis but also from equalizing (present value) marginal costs intertemporally as firms have saved current permits for future used in what is known as banking of permits. According to (Ellerman and Montero, 2007), the use of banking has been substantial and remarkably close to what would be expected in a well-functioning market. Recently the price has collapsed to zero also in this market as the EPA has used other instruments to push for further reductions.

Banking has also been responsible for a large part of the significant cost savings in the US Lead Phasedown program ---a trading scheme established in 1982 to provide refineries with flexibility to gradually remove lead from gasoline. In addition to banking, cost savings in this program were driven

[7] Note that there is literature (e.g., Lohmann (2008)) much less enthusiastic about the concept of emissions trading for reasons of justice and environmental integrity, among others, and more so after the current collapse of carbon prices in the EU-ETS, (Lohmann, 2008).

by dynamic efficiencies, i.e., the faster adoption and/or development of more efficient refining technologies (Kerr and Newell, 2003). In contrast, dynamic efficiency has played a minor role in explaining cost savings in the US SO2 allowance program (e.g., Ellerman et al., 2000; Fowlie, 2010; Kumar and Managi, 2010).

The introduction of a price on carbon through either a carbon tax or cap and trade can have substantial distributional consequences. Extensive analyses of these effects have been conducted in the U.S. context. Burtraw et al. (2009) illustrate in the context of a trading program that the outcome for the average household will depend much more importantly on the use of the value associated with emissions allowances than with the actual stringency of the regulation. For example, lump sum dividends or some kinds of tax reform can be progressive. Similarly Hassett et al. (2009) find that the degree of regressivity is much reduced when a lifetime measure of income is used. Parry (2004) shows in an analytical framework that emissions trading can be regressive, especially if implemented with free allocation to incumbent emitters (grandfathering). Bovenberg et al. (2005) find that profits can be maintained throughout the economy by freely allocating less (sometimes considerably less) than 25 percent of pollution permits, with the rest auctioned. These considerations are very similar for tax or cap and trade systems. Granting greater than this quantity for free would lead to windfall profits. In simulation modeling of the US electricity market, Burtraw and Palmer (2008) find that it would be sufficient to allocate just 6 percent of the allowances to the electricity industry to offset costs under a CO2 trading program because a majority of costs are borne by consumers; greater allocation would again lead to windfall profits. Hassett et al. (2009) examine regional effects and find them not to be very significant. Blonz et al. (2012) show that even if programs are regressive, social safety nets which adjust automatically to inflation generally protect low-income groups in the US, and middle income groups may be most vulnerable.

It should be noted that the experience with emissions trading, whether for greenhouse gases or other, non-climate-related pollutants, has been wholly in high-income countries. Coria and Sterner (2010) describe some success for air pollution in a middle income country like Chile but it is unclear to what extent these can be transferred to developing countries.

15.5.3.3 Sector coverage and scope of the cap

A key component in a trading scheme is establishing the pollutants (e.g., greenhouse gases) and entities that will be regulated. There are several factors that may affect this decision: the quality and cost of emissions measurement and verification, targeting sectors with the greatest mitigation potential, broadening the coverage to unlock low-cost mitigation opportunities, the political and institutional feasibility of including certain sectors, as well the interactive effects the cap may have with other policies.

In most trading schemes, the affected sources are relatively large emitting sources whose emissions have been closely monitored (smaller sources are often regulated with alternative instruments). This applies to the earlier programs (e.g., Acid Rain, RECLAIM, Lead Phasedown)[8] but also in carbon markets. In other words, there are few cases in which the point of obligation has been upstream, i.e., different than the emitting point. The trading scheme in Australia, launched in 2012, covered 373 entities comprising approximately 60 percent of Australia's GHG emissions. Electricity generation, industrial processes, fugitive emissions and non-legacy waste are under permit liability (Clean Energy Regulator, 2012).[9] Small-scale stationary fossil fuel use (especially gas) is covered by

[8] An exception is the market for particulates established in Santiago-Chile in 1992 for industrial sources (Montero et al., 2002). The trading commodity was not actual emissions, which were difficult to monitor on a daily basis, but a firm's maximum capacity to emit.

upstream permit liability on fuel distributors. Liquid fuels used in aviation/shipping and synthetic greenhouse gases are subject to an equivalent carbon price through changes to existing taxes. Agriculture and forestry can produce offset credits (Macintosh and Waugh, 2012; Caripis et al., 2012).[10]

Coverage in the carbon trading scheme in New Zealand, is the most comprehensive and covers all GHGs and all sectors. It has expanded in stages from the forestry sector (in January 2008) to fossil fuels and industrial emissions (in July 2010), with the waste and agricultural sectors to be included from 2013 and 2015 respectively. It is the only national emissions trading scheme to include forestry, and is intended to shift land-use change decisions towards greater carbon sequestration and less deforestation (Karpas and Kerr, 2011; Adams and Turner, 2012). Coverage is also scheduled to expand in stages in the recently launched carbon market in California (Hanemann, 2009). In the first compliance period, which runs from 2013–2014, electricity generating and industrial facilities that exceed 25,000 tonnes of CO_2e per year will be obligated to abide by the agreement; the second period (2015–2017) adds distributors of transportation, natural gas, and other fuels; and the third period (2018–2020) adds transportation fuels (CARB, 2011). All major sources will be covered over time, which will represent an equivalent of 85% of California's GHG emissions (CARB, 2011).Offset projects are foreseen in forestry management, urban forestry, dairy methane digesters, and the destruction of ozone-depleting substances.

There are other carbon markets that are less ambitious in scope. The trading scheme in Tokyo, launched in April 2012, includes 300 industrial facilities - which in total consume at least 1,500 kl of crude oil equivalent per annum - and a combined 1,000 commercial and institutional buildings. In aggregate, this is equivalent to only 20% of Tokyo's total CO_2 emissions (Partnership for Market Readiness, 2012). Though the program may be limited in scope, it is one of the first programs in the world to address emissions from urban buildings, which can be quite significant (Nishida and Hua, 2011). The Regional Greenhouse Gas Initiative (RGGI), a cap−and−trade program initiated in 2009 and that covers nine Northeast and Mid−Atlantic states in the U.S. (Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont), only regulates CO_2 emissions from power plants.

15.5.3.4 Setting the level of the cap

The cap defines the stringency of the trading scheme. Naturally the permit prices also depend on many circumstances such as the economic growth. In many of the trading programs reviewed above, the caps appear however to have been set below what would lead to efficient levels of abatement – since the allowance prices (the marginal abatement costs) have ended up below most estimates of the marginal environmental benefits from abatement. The RECLAIM program which covers NOx and SO_2 is an example as are the acid rain and lead phase-out programs. It should be noted, however, that to varying extents, carbon trading programs include mechanisms to tighten the cap gradually.

Caps in the carbon markets have slower reductions maybe because of higher short-term mitigation costs. In the Australian scheme, there is no cap on emissions during the initial so-called "fixed-price phase" (2012-2014) but a price that rises from Aus$23.00 per tonne in 2012/2013 to Aus$25.40 in 2014/2015. The fixed price scheme, has many of the characteristics of a tax and offered advantages in the specific political circumstances that failed to agree on an emissions target but not on a price (Jotzo et al., 2012) hence preferring implicitly uncertainty on emissions rather than on the price (Jotzo and Betz, 2009; Jotzo and Hatfield-Dodds, 2011; Pearce, 2012). The fixed price period

[10] For more see section 7A of the National Greenhouse and Energy Reporting Act 2007 (Commonwealth of Australia, 2007). The carbon market in South Korea, to start in 2015, will cover around 450 large facilities and about 60% of the country's GHG emissions (Kim, 2011).

naturally established a price signal and provided time for important elements of the flexible price period to be implemented, such as an auction platform. Starting with the first flexible-price phase (2015-2018), the government will set annual caps for five-year periods, extending the cap by one year every year. A default cap (associated to a GHG emissions reduction of 5% from 2000 levels by 2020) will apply in the event the parliament cannot agree on a cap (CAUS, 2012).

New Zealand, on the other hand, has operated within the Kyoto cap for 2008–2012 by requiring every unit of emission to be matched by a Kyoto unit at the end of the Protocol's true-up period. For 2012 and forward, the government has proposed legislative amendments to introduce a domestic cap and remove the requirement to back domestic emission with Kyoto units.(NZME, 2013)

The cap in the California scheme is set in 2013 at about 2% deviating under the projected level for 2012, and then drops about 2% in 2014 and about 3% from 2015 to 2020 on an annual basis (four percent of allowances will be held in reserve to contain costs). RGGI has introduced a "soft" fixed cap from 2009 to 2014 to decline by 2.5% per year. Economic growth and natural gas prices have been lower than expected, so it is unlikely that the cap becomes binding by 2020 (Aldy and Stavins, 2012).[11]

15.5.3.5 Allocations

There are basically three ways in which permits are allocated: free through grandfathering or output allocation, and auctioning. Earlier programs relied almost exclusively on grandfathering. The SO2 allowance program allocated less than 3% of the total cap, through revenue-neutral auctions; mainly to provide an earlier and more reliable price signal to participants (Ellerman, Convery, De Perthuis, et al., 2010). Some of the recent carbon markets also provide free allocations because of concerns about emissions-intensive trade-exposed industries. In fact, the program in New Zealand considers a very limited amount of auctioning (although increasing over time) unlike RGGI which allocates the vast majority of permits through auctions (the softer cap in RGGI may explain the difference). Australia and California are somewhere in the middle in terms of auctioning, roughly 50% and 80% respectively.

The Californian and Australian schemes also make explicit output-based (free) allocation rules for energy-intensive, trade-exposed sectors, where recent production determines firm-level allocation. The Australian experience on this matter has also shown the influence that industry lobby groups can have in policy design (Garnaut, 2008; Pezzey et al., 2010) and how politically involved this can become (Macintosh et al., 2010).

15.5.3.6 Linking of schemes

Linking occurs when a trading scheme allows permits from another trading program to be used to meet domestic targets. Such linkages can be mutually beneficial as they can improve market liquidity and lower costs of compliance. However, these benefits need to be weighed against challenges like losing unilateral control over domestic design and being subject to international price movements. Linking, however, involves certain trade-offs in terms of exposure to international prices and loss of flexibility to unilaterally change features in the domestic design once links are established. International linkage of trading schemes might be simpler than harmonizing carbon taxes through international agreements (Karpas and Kerr, 2011). There is however not general agreement on this point; To the contrary, agreements on taxes might avoid the most contentious baseline issues see for instance (Nordhaus, 2007).

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[11] There is a proposal from the RGGI States, however, to reduce the cap in 45% by 2020 (Regional Greenhouse Gas Initiative, Inc., 2013).

The experience with linking is limited because carbon markets are relatively recent. One example of a linking process is the ongoing collaboration, since 2007, between California and the Canadian province of Quebec, which will both place compliance obligations on large emitters under their trading schemes beginning in January 2013 and continue negotiations for a full linking of the two schemes later on in 2013 (CARB, 2011). Another example is last year's announcement of an Australia-EUETS link by 2018 preceded by a transition phase in which Australian installations can use EU-Allowances for compliance from 2015 on. Interestingly, Australia is also exploring ways for establishing links with schemes in South Korea and California, which, de facto, would create links between all these trading schemes.[12] We do not yet know if linking schemes without prior commitment on overall caps will facilitate or complicate future negotiations on the caps.

15.5.3.7 Other design issues: banking, offsets, leakage, price volatility and market power

There are additional, important, aspects of policy design on which we can only briefly touch here. Unlike borrowing, banking of permits for future use is a feature used in many trading schemes with good results in terms of cost savings and environmental benefits (i.e., absence of emission spikes and acceleration of emission reductions). A well-documented example is the US SO2 allowance program (Ellerman and Montero, 2007). A dramatic example of volatility is given by the RECLAIM program where in the summer of 2000 permit prices that began under $5,000 per ton of NOx increased abruptly in price to almost $45,000, leading to a relaxation of the cap see (Metcalf, 2009). Offsets, the possibility of using emission credits outside the capped sectors either domestically or internationally (e.g., CDM or REDD), is another design feature common in most trading schemes but of much concern because of the well-known tension between cost-effectiveness and additionality. One way to somewhat assuage this tension is to move away from a project-based crediting approaches (e.g., CDM) to scaled-up approaches ---to the level of the sector, jurisdiction or country. Offset provisions, if well designed, can also help alleviate the "leakage" problem of moving emissions from capped to uncapped sectors. An alternative design option to address leakage might be to use output-based allocation rules although this will raise concerns related to output subsidy. Another problem is market power specific to permit trading which has been the subject of much research since the work of (Hahn, 1984). It seems, however, that market power is less of a problem than anticipated (Liski and Montero, 2011), , also confirmed by findings from laboratory experiments (Sturm, 2008).

15.5.3.8 Choice between taxes and tradable permits

Regarding the choice between taxes and tradable permits, longstanding economic theory (Weitzman, 1974; Hoel and Karp, 2001, 2002; Newell and Pizer, 2003) suggests that in the presence of uncertainty about the marginal cost of emission reduction, for a stock pollutant like CO2, a carbon tax is more economically efficient than a tradable permit system. According to the Weitzman intuition a tax is preferred since the benefits curve is fairly flat for a stock pollutant, (this result could be changed in the presence of a major threshold effect). The reason is essentially that when there is a negative shock to the cost of emission reduction, as has been the case in the EU following the economic slowdown that began in 2008, cost efficiency calls for doing more abatement, with less being done at other times when the abatement cost is higher. This is achieved with a tax, but not with a cap that is fixed in each period. The slump in the carbon price in the EU ETS is thus suggestive of a loss of cost-effectiveness.

[12] The firm intentions of New Zealand and Australia about linking their systems came to a sudden end after the latter announced it was linking its system to the EU ETS.

In the very long run there may be more uncertainty about the level of an optimal tax than about a quantity target and policy makers may then prefer to legislate a long-run abatement target in a cap-and-trade system. As seen above, this can entail short-run efficiency losses and it would be desirable to allow flexibility with regard to annual caps that would add up to the long run target, but concerns about credibility mean that such flexibility must be severely limited. As shown in chapter 2 (section 2.6.5), there is a literature on regulatory uncertainty that shows extra costs deriving from the hesitancy by investors in the face of all regulatory uncertainty but in particular perhaps, when it comes to cap and trade systems

To prevent a large loss of efficiency in a cap and trade system, and to avoid exceptionally high price volatility that deters investment, price floors and ceilings can be used, although care would be needed in design to avoid breaching the integrity of the cap. Banking and borrowing of permits (see 15.5.3) are another means of providing intertemporal flexibility in abatement as are the availability of credit reserves or of offsets.

As explained in 15.7, a tax can be used in conjunction with other policy instruments while a cap-and-trade system either renders the other policies environmentally irrelevant or is itself rendered environmentally irrelevant by them. This is a major concern when decision-making takes place at several levels.

As discussed in 15.5,2,4, the issues of intertemporal (and spatial) leakage discussed in the Green Paradox literature would appear to give preference to cap and trade over taxes but this is partly a simplification. The green paradox mainly exists in oversimplified models and poorly designed tax schemes. There are however lessons from this literature concerning design details. For example one might prefer high taxes that grow slowly to low taxes that rise very fast and one might be careful with too much flexibility, particularly borrowing in permit systems. Kalkuhl and Edenhofer (2013) compares four policies, a conventional Pigouvian carbon tax, a carbon tax rule (that adjusts the tax level dependent on GHG concentrations), and permit trade (with or without banking and borrowing) in the context of a (weak) green paradox setting with respect to three different criteria: The informational burden for the government, the commitment problem of the government and the robustness of the policy with respect to deviations in behaviour (discount rate) by agents in the economy. They find that a tax and a trading scheme without banking and borrowing have high informational requirements. The ETS with banking and borrowing shifts the timing problem of carbon emissions to the private sector but does not work well if these have different discount rates from the regulator. The flexible tax rule or an ETS with restricted banking and borrowing can lead to an optimal allocation even in this case but then again the informational requirements for the regulator are daunting.

One of the attractions of emission trading schemes appears to have been that they may meet with less opposition from industry who can be allocated permits for free. Taxation is often resisted by lobbies and sometimes for constitutional reasons. Taxation if also resisted by those who want a smaller government – in which case environmental fiscal reform (raising carbon taxes while lower other taxes) may be more acceptable. Another argument that has been made in favour of an ETS is that it may be easier to link permit schemes across borders than to agree on common taxes. Harmonization is advantageous, since it reduces costs (15.7). There is however no general agreement on this. Some analysts believe the opposite, that it will be easier to link taxation systems within an international agreement, (Helm, 2003; Nordhaus, 2007; Jaffe et al., 2009; Metcalf and Weisbach, 2011) and 15.8.1. Finally, linking cap and trade systems would automatically involve financial transfers between countries. These might be a benefit for low income countries if they can be carbon-efficient and maybe less controversial than negotiated side payments but this hinges on agreement concerning the various country targets.

Finally taxes, unlike an emission trading scheme, do not require a new institutional infrastructure to keep track of ownership of emissions allowances. This consideration may be especially important in developing countries.

15.5.4 Regulatory Approaches

15.5.4.1 Introduction

As discussed in 15.2, economy-wide carbon pricing, though widely discussed in the literature, has been rarely implemented. Those policies that have been implemented have often been sector-specific, and have often fallen in the category of a regulatory approach. Regulatory approaches are used across sectors, usually alongside other policies, as can be seen in Table 15.2. For example, Renewable Portfolio Standards (RPS), and energy efficiency standards may be combined with fuel subsidy reduction in the energy sector (Chapter 7). In the transport sector, vehicle efficiency and fuel quality standards are used alongside government provision of mass transit, and fuel taxes (Chapter 8). In the building sector, a number of complementary policies, such as appliance standards, labelling, and building codes are employed, along with tax exemptions for investment in energy-efficient buildings (9.9). In the industrial sector, energy audits for energy-intensive manufacturing firms are also regularly combined with voluntary or negotiated agreements and energy management schemes. Information programs are the most prevalent approach for energy efficiency, followed by economic instruments, regulatory approaches and voluntary actions (10.11).

Several of these regulatory approaches often contain market-like features so that the distinction between regulatory approaches and economic instruments is not always sharp. RPS programs often, for example, allow utilities to satisfy their obligations by purchasing renewable energy credits from other producers while feed-in tariffs involve both regulations and subsidies for renewable energy. Low-carbon fuel standards also sometimes incorporate market-like features including trading among suppliers.

Regulatory approaches play the following roles in climate mitigation policy. First, they directly limit greenhouse gas emissions by specifying technologies or their performance. Second, in sectors such as AFOLU (see Chapter 11) and urban planning (see Chapters 8 and 12) in which much activity is strongly influenced by government planning and provision, regulations that take climate policy into account are clearly important. These are discussed in further in Section 15.5.6. Third, regulations such as RPS can promote the diffusion and innovation of emerging technologies, a role that is examined in Section 15.6. Fourth, regulations may remove barriers for energy efficiency improvement. These may arise when firms and consumers are hindered by the difficulty of acquiring and processing information about energy efficient investments, or have split incentives as in landlord-tenant relationships.

Regulatory approaches have been criticized, both for being environmentally ineffective, and more strongly, for lack of cost-effectiveness, as the governments have limited information and may make governmental failures in intervention ((Helm, 2010) See also 3.8.2)). Some are opposed to the regulations on libertarian philosophical grounds (Section 3.10.1.1). In what follows, we assess the environmental and cost effectiveness of regulatory approaches, largely focusing on short-run effects of energy efficiency policies that have been extensively studied. Long-run effects acting through technology development are assessed in Section 15.6. There is insufficient literature on distributional incidence and feasibility to underpin an assessment of these dimensions.

15.5.4.2 Environmental effectiveness of energy efficiency regulations

Several prospective studies reviewed by Gillingham, Newell and Palmer (2006a) and one large ex-post study of US energy efficiency standards for appliances (Meyers et al., 2003) found substantial energy savings. Such savings have also been found in the building sector across countries (Ch 9.10) in a study of best-practice building codes and other standards. Recently, econometric studies in the US have also found energy reductions from building codes (Aroonruengsawat, 2012; Jacobsen and Kotchen, 2013). These studies also reported significant energy savings and related CO2 reduction. Fuel economy standards for vehicles have also been successful in reducing fuel consumption in many countries (Anderson et al., 2011). Generally speaking, energy efficiency policies that address market failure can result in energy savings ((7.10, 8.10, 9.10, Table 9.8, 10.10). Some case studies however, identified weak environmental effectiveness due to lack of implementation. Such examples were found for building codes and energy management systems.

Rebound effects need to be taken into account in interpreting these findings of environmental effectiveness of energy efficiency regulations. The rebound effect refers to the increase in energy consumption induced by a fall in the cost of using energy services as a result of increased energy efficiency. For detailed general discussion on rebound effects, see 3.9.5 and 5.6.2. For sector-specific studies of rebound effects, see 9.6.2.4 for building sector and Chapter 8 for transport sector. With regard to appliance standards and fuel-economy regulations in the US, environmental effects remain large even when taking the rebound effect into account (Gillingham et al., 2006a; Anderson et al., 2011). More generally, direct rebound effects (within the regulated sector as a result of the fall in the cost of energy services) are commonly found to be in the range of 10% -30% in various sectors in developed countries, and higher in developing countries (Sorrell et al., 2009; Gillingham et al., 2013). Indirect rebound effects, that result from increased economic growth resulting from the fall in the cost of energy services, can be much larger. Reviewing claims of rebound effects in excess of 100%, (Dimitropoulos, 2007) concluded that although the evidence base and methodologies were weak, the possibility of significant rebound effects could not be dismissed. A recent review suggests that total rebound effects are unlikely to exceed 60% (Gillingham et al., 2013).

While the scale of the rebound effect varies, its presence suggests that complementary policies that include carbon pricing are called for so that mitigation is not compromised. Some countries, such as the UK, have begun to account for a direct rebound effect in energy policies (Maxwell et al., 2011).

Regulations such as emissions standards have also been criticized on the ground that they are less flexible than incentive-based approaches and may even provide perverse incentives and increase emissions under certain conditions like treating new units more stringently than old ones (Burtraw et al., 2010). Yet recent modelling that incorporates institutional features of various policies in the United States, including the capacity to adjust the stringency of a regulation or a cap/tax, suggests that emissions standards may be more effective than cap-and-trade in reducing overall emissions (Burtraw and Woerman, 2013).

15.5.4.3 Cost effectiveness of energy efficiency regulations

Regulatory approaches are often implemented in contexts in which market failures or barriers to adoption of energy-efficient technologies exist. There is a considerable sectoral literature showing that energy efficiency regulations have been implemented at negative costs to firms and individuals, meaning that their value to consumers exceeded program costs on average. In the transport sector, fuel economy standards have been shown to produce net cost savings over the life of the vehicle (8.10). In the building sector, a range of energy efficiency policies including appliance standards and building codes have been found to have negative private costs (Table 9.8), (Gillingham et al., 2006a, 2009a). In the industrial sector, a number of case studies on energy management systems and energy audit systems show that they have been cost effective (10.10).

The cost effectiveness of such regulations has been the subject of heated debate. Economic theory points to the following circumstances in which regulations may be implemented with negative private costs. Buyers may have less information about the efficiency and cost of a device than sellers. They may not be able to assess the energy savings from an appliance even after using it. This can lead to a situation in which low-efficiency devices drive more expensive high-efficiency ones out of the market. Efficiency standards in this setting can improve consumer welfare by reducing the informational asymmetry between buyers and sellers (Akerlof, 1970; Leland, 1979; Goulder and Parry, 2008). When competition is imperfect and sellers compete on both quality (efficiency) and price, then a minimum quality standard eliminates low-quality sellers from the market enhancing price competition among high-quality goods. This can make all consumers better off (Ronnen, 1991). Split incentives, as in landlord-tenant relationships can lead to economically inefficient devices persisting in the market, absent intervention. For more details, see Box 3.9.2.

For individuals and small workplaces, it is difficult to get and analyse information on energy efficiency (see 2.6.5.3 on human behaviour on energy efficiency). As a consequence, they are prone to rely on intuition to make decisions. Analysing the minimum cost actions given the price signal is too difficult for them. Cognitive costs may result in some consumers simply not taking operating (energy) costs into account at all while making their purchase decisions (Section 3.10.1.1). This was the case with 40% of US car buyers in a recent survey (Allcott, 2011). This can lead sellers to offer less energy efficient products than these consumers would buy if they could compute the consequences. Section 9.8 indicates that such barriers to energy efficiency are significant in the building sector. Regulation and information measures can help overcome these barriers.

Large firms have more resources than individuals to assess information on energy efficiency and so may be more sensitive to carbon pricing. However, firms, in particular small and medium enterprises, also face the barriers such as split incentive and lack of information. Government may employ regulations (and information measures) to help correct this by implementing energy efficiency standards for equipment, for example. See 3.10.1.2 for more on behaviour of firms on energy efficiency.

Although both the theory and empirical evidence detailed above show that policy interventions to remove barriers can have negative costs to firms and individuals, it has been argued that unaccounted labour and opportunity costs borne by governments, firms and individuals involved in policy design and implementation process, as well as loss of amenity (for example, fuel economy standards may undermine other functions of cars, such as speed, safety, quality of air conditioning and audio sets), result in understatement of regulatory costs. Such unaccounted costs are called “hidden costs”(Box 3.9.2)

On the other hand, an ex-post evaluation of expected and realized costs of environmental regulations in the US found that estimates of the unit cost of regulations by the regulator, were overstated just as often as they were understated, while total costs were more frequently overstated (Harrington et al., 2000). Furthermore, Gillingham et al (2006a) note that in the US, “even if unaccounted-for costs of appliance standards were almost equal to those measured, and actual energy savings only roughly half of those estimated, appliance standards still would yield positive net benefits on average” (Gillingham et al., 2006b). There may also be hidden benefits of regulations, (Sorrell, 2009), such as improved amenities and “free drivers” (which would occur if nonparticipants were induced to invest in energy efficiency because others in the program made such investments) induced by regulation (Gillingham et al., 2006a). In conclusion, while it is clear that opportunities do exist to improve energy efficiency at negative private cost by regulations, the literature is divided as to what extent such negative private cost opportunities exist.

It is the social rather than the private costs of regulations, however, that are more relevant for public policy. This means that externalities need to be taken into account and co-benefits of policies, such as local air pollution reduction, valued and subtracted from costs. Such externalities can be large. Muller, Mendelsohn, and Nordhaus (2011) found that the external costs of coal-fired utilities in the US exceeded value-added in that sector. These and other costs and benefits have to be taken into account when evaluating policies.

15.5.5 Information Measures

Information measures have been widely used in all sectors. To take typical examples, energy efficiency labelling for home electric appliances and thermal insulation of buildings, as well as carbon footprint certificates and public awareness initiatives are implemented in building sector (9.10). Energy management systems as well as government-assisted energy audits, either mandatory or voluntary, are used in building, industry, and energy sector (7.10, 9.10, 10.10). Mandatory reporting of GHG emissions is common for firms in the power and industrial sectors (7.10, 10.10), while labelling of automobile fuel economy is used in the transport sector (8.10). Sustainability certificate programs are used in the forestry sector (11.10).

Regarding the environmental and economic effectiveness, a number of case studies in building sector are shown for the energy efficiency labelling for home electric appliance, building label and certificates, energy audit programs, and awareness raising campaign to stimulate behavioural change (9.10, Table 9.8). For energy efficiency, the role of information measures is the same with regulatory approaches, that is to address market failure such as lack of information and split incentives. For details of the market failure and role of information measures, see 15.5.4.

While some studies mentioned above reported high economic and environmental effectiveness, the results are mixed in general, reflecting the wide diversity of the information measures and it is not appropriate to draw a general conclusion. Note that some policy instruments, such as energy management systems and energy audit in industrial sector that may fall either in regulatory approach and information measures, are also covered in the section on regulatory approach above.

Since information programs typically provide information and leave it to firms or consumers to take appropriate action, those actions will usually only be taken spontaneously, or if they are perceived to have negative private costs economically. The discussion of hidden costs/benefits and rebound effects parallels that of regulatory approach, see above (15.5.4).

It should be noted that the role of information measure has been mostly supplementary to other policy instruments such as obligatory standards or much wider policy package as detailed in sector specific policy chapter (7.10, 8.10, 9.10, 10.10, 11.10). For example, energy efficiency labelling is often followed by energy efficiency standard as a single policy package. This also makes difficult to estimate the impacts of the information measure alone.

15.5.6 Government Provision of Public Goods or Services

While formal assessment is difficult, it is clear that public provision and planning can and have played a prominent role in the mitigation of climate change at the national and sub-national levels, and in a wide range of industries including energy, transport, agriculture, forestry, and others. At the national level, government provision or funding is crucial for basic research into low and zero-emission technologies (see 15.7 below).

In the energy sector, the provision and planning of infrastructure, whether for electricity transmission and distribution or district heating networks, interconnectors, storage facilities etc., is complementary to the development of renewable energy sources such as wind and solar energy (7.6.1.3). A modal shift from air to rail transport also requires public planning or provision by national and local governments as a part of the policy mix and in best-case scenarios could reduce associated emissions by 65-80% (8.4.2).

Urban planning that incorporates climate mitigation can have a major impact on emissions (Chapter 12); therefore, municipal governments have a very important role to play.. Since climate mitigation policies have many co-benefits at the local level, including reduced local pollution and congestion, and improved quality of urban space, cities have an interest in mitigation policies in addition to the largely external climate benefits they provide. Land-use and transport policies can considerably influence the share of non-motorized transport, public transport, and associated emissions (8.4.2.3). Buildings and associated energy supply infrastructure are very long-lasting (9.4.5) so public planning to encourage the rapid adoption of new low-carbon technologies and avoid lock-in to high-emission infrastructure assumes importance. Such planning would need to take into account transport pricing relative to land prices, building, parking, and other zoning regulation, city-wide district heating and cooling systems, and green areas (see section 12.5, and (Baeumler et al., 2012). Capacity building at the municipal level may be needed for incorporating GHG mitigation and its co-benefits into the planning process, especially in developing countries (see 15.10.3).

Government planning and infrastructure provision can complement a carbon or fuel tax, addressing additional market failures increasing the quantity response to the price instrument by making substitution towards less energy and carbon-intensive lifestyles easier. Conversely, whether or not a public transit system will generate sufficient demand to be economical, depends on whether private transit (and its climate externalities) is suitably priced. By contrast, as noted below in 15.8, a tradable permit system for emissions would be a substitute, rather than a complement for emission reduction through public provision. In conjunction with a tradable permit system, local actions would affect the cost of reducing emissions, but not overall emissions themselves. This raises the possibility that local governments may be de-motivated to integrate GHG mitigation in their planning if they are located in a national or international jurisdiction with a tradable permit system. In that case, their actions would not be `additional’ in GHG emission reduction. Rather they would reduce the cost of meeting the overall cap. Furthermore, the cost reduction would not be captured entirely by the residents of the local jurisdiction in which the actions took place.

Since most of the world’s forests are publicly owned, provision of sequestration services as part of forest conservation is largely in the public sector. Forest protected areas make up 13.5 % of the worlds’ forests, and 20.8% for tropical lowland evergreen broadleaf forests (rainforests) (Schmitt et al., 2009). During the period 2000-2005, strictly protected forest areas experienced 70% less deforestation than all tropical forests (Campbell, A. et al., 2008), but impact studies must also control for ‘passive protection’ (protected areas being located in remote and inaccessible areas), and ‘leakage’ (more deforestation outside the protected area). The understanding of how protected areas can contribute to forest conservation, and thereby be a means of climate mitigation, has advanced much since AR4, due to better spatial data and methods.

(Andam et al., 2008) find substantial passive protection for protected areas in Costa Rica. While a simple comparison suggests that protected areas reduce deforestation by 65%, the impact drops to 10% after controlling for differences in location and other characteristics. (Gaveau et al., 2009) estimate the difference between deforestation rates in protected areas and wider areas in Sumatra, Indonesia during the 1990s to be 58.6%; this difference falls to 24% after propensity score matching which accounts for passive protection. In a global study, also using matching techniques, (Joppa and Pfaff, 2011) finds that for about 75% of the countries, protected areas reduce forest conversion, but that in 80 % of these controlling for land characteristics reduces the impact by 50% or more. Thus, an emerging consensus is that protected areas reduce deforestation (Chomitz et al., 2007), even though protection is not perfect, and there is a medium to high degree of passive protection. Estimates of leakage are more challenging, as the channels of leakage are diverse and harder to quantify.

Local governance of forests can be an effective way of reducing emissions from deforestation and forest degradation, as at least some of the public goods provided by forest are included in the decision-making. A meta-analysis of 69 cases of community forest management finds that 58% of these were successful in meeting ecological sustainability criteria, e.g. “improved forest condition” (Pagdee et al., 2006). Similarly, using data from 80 different forest management units in 10 countries, a study found positive correlation between greater devolved authority at the local level with higher levels of carbon sequestration (Chhatre and Agrawal, 2009). However, a study analyzing forest cover of central Himalaya in India that controls for confounders reports no statistically significant results (in forest cover) between village and state-managed forests, even though the costs per Ha are seven folds greater for the state-managed forests (Somanathan et al., 2009).

Where property rights are insecure, strengthening land rights is often put forward as a way to contain deforestation, though the effects are ambiguous. It is argued that the lack of tenure rights can discourage investment in land and increase soil exhaustion. This would, in turn, lead to greater incentives to deforest to compensate for the lost productivity due to degradation. Unclear tenure can also lead to unproductive and violent land conflicts (Alston et al., 2000). However, by increasing the value of land clearing, policies that strengthen private property rights over land could increase deforestation. (Angelsen, 1999).

15.5.7 Voluntary Actions

15.5.7.1 Introduction

It has become quite common for major firms, either individually or in alliance with others, to commit to mitigation of climate change as part of their corporate social responsibility through emission cuts at their offices and facilities, technological research, development, and sales of climate friendly equipment (See IPCC AR4). NGOs also initiate voluntary actions (See 15.9).

This section focuses on voluntary agreements that are convened by industries in association with government. Voluntary agreements have been developed in very different ways in different nations, depending on their institutional and corporate culture background. In what follows the literature will be reviewed according to the three categories provided by (Pinkse and Kolk, 2009).

15.5.7.2 Government-sponsored voluntary programs for firms

Government-sponsored programs for firms, where participation is completely voluntary and there are no penalties for not participating in the agreement, have been implemented in several countries, including the US and Australia. US EPA led voluntary programs foster partnerships with industry and the private sector at large by providing technical support among other means (US EPA, 2013).

Ex-post case studies on the environmental and economic effectiveness have been scarce compared to the wide range of activities. Where available, they have been critical of this type of program. Several studies say little reduction was achieved (see (Brouhle et al., 2009) analysing a voluntary program in the U.S. metal-finishing industry) or the impacts were short lived, as was the case for the US Climate Wise Program (Morgenstern et al., 2007). See also (Griffiths et al., 2007) and (Lyon and Maxwell, 2004) who conclude the US Climate Leaders program had little effect on firm behaviour.

15.5.7.3 Voluntary agreements as a major complement to mandatory regulations

Voluntary agreements often form a part of a larger climate policy approach that contains binding policies such as a carbon tax or a cap and trade program. Voluntary agreements conducted jointly with mandatory regulations have been widely implemented in Europe (Rezessy and Bertoldi, 2011).

This approach allows the regulated industries to use the voluntary agreement as a partial fulfilment of the mandatory regulation. For example, through participation in the Climate Change Agreements (CCA) in the UK, energy intensive industrial sectors established targets to improve energy efficiency and the companies that met such targets received an 80% discount from the Climate Change Levy (CCL) (Price et al., 2008). Likewise, the Dutch government ensured industries participating in Long-Term Agreements (LTA) were not subject to additional government policies regulating CO2 emission reductions or energy conservation and that the new energy tax would not be levied on the participating industries. In both cases participants established a long term plan to save energy and reduce CO2, and implemented energy management systems (Price et al., 2008; Stenqvist and Nilsson, 2012).

Some studies found that the voluntary agreements were environmentally and economically effective. (Bressers et al., 2009) found positive results in terms of ambition, compliance, goal attainment and behavioural change. They also acknowledged the efficiency advantages of flexibility in phasing technical measures. (Ekins and Etheridge, 2006) analysed the UK CCA and found that, while the targets were not very stringent and were generally achieved in advance of the set date, the CCAs appeared to have catalyzed energy savings by increasing awareness. This allowed the net environmental benefits to exceed what would have been achieved by levying a flat tax without rebates and CCAs while also generating economic gains for the companies under the CCAs (Ekins and Etheridge, 2006).

Rezessy and Bertoldi (2011) assessed the effectiveness of voluntary agreements in 9 EU member countries. In cases where there is cooperative culture between governmental entities and the private sectorexist, VAs can have some beneficial effects compared to legislation. They include willingness by the industry, sharing of information, flexibility in phasing measures, fine-tuned solutions to individual industries. They emphasized that by engaging signatories in energy audits, consumption monitoring, energy management systems and energy efficiency project implementation, the voluntary agreements helped overcome the barrier for energy efficiency improvement in a systematic manner. Nevertheless, they also noted that the VAs had been criticized for lenient targets, deficiencies in monitoring, and difficulty in establishing the additionality. There are other critical studies. Bohringer and Frondel (2007) argued that they found little evidence that the commitment of the German cement industry was effective, due to weak monitoring. Martin et al. (2011)concluded that the CCL had strong negative environmental impacts. Voluntary agreement between the European Commission and the car industry which set a mid-term target of 25% reduction on CO2 emissions from automobiles by 2008 completely failed (Newell and Paterson, 2010).

15.5.7.4 Voluntary agreements as a policy instrument in governmental mitigation plan

Voluntary agreements may be used as a major policy instrument with wide coverage and political salience in a governmental mitigation plan. This type of voluntary agreements has been implemented in Japan and the Chinese provision of Taiwan.

The Japanese Voluntary Action Plan (VAP) by Keidanren (Japan Business Federation) was initiated in 1997. The plan, led by Keidanren and joined by 114 industrial associations, covered about 80% of greenhouse gas emissions from Japan's industrial and energy transformation sectors. The plan is embedded in the regulatory culture in which the government constantly consults with industrial associations. It was reviewed annually in governmental committees, and an independent third party committee was also established to monitor its implementation; the included industries were required to be accountable with their environmental performance constantly. Industrial groups and firms established energy and GHG management systems, exchanged information, being periodically reviewed and acted to improve energy efficiency and cut GHG emissions. Several industry sectors raised the ambition levels with stricter targets during the course of VAP, once they achieved original targets (Tanikawa, 2004; Akimoto, 2012a; Uchiyama et al., 2012; Yamaguchi, 2012). An econometric analysis found that voluntary actions by the manufacturing sector led to significant energy efficiency investments (Sugino and Arimura, 2011).

Two successful case studies in VAP have been reported. In cutting stand-by power by electric appliances, three major industrial associations announced 2001 the target to limit stand-by power less than 1Watt for all electric appliances to be met by 2003. It was possible for them to commit to the ambitious targets – ambitious in terms of the level of target (1W), wide coverage of appliances, and early timing of goal – exactly because it was voluntary, not mandatory. In contrast, other countries that took a regulatory approach have implemented much weaker targets at later dates, and the coverage of appliances had been small. By 2003, almost all appliances met the target on time in Japan. Also, semiconductor industrial associations committed to cut Perfluorocarbons (PFC) emissions in 1998 and succeeded in reduction by 58% by 2009. (Wakabayashi, 2013)

Chen and Hu (2012) analysed the voluntary GHG reduction agreements of six different industrial sectors, as well as the fluorinated gases (F-gas) reduction agreement of the semiconductor and LCD industries in Chinese provision of Taiwan. They found that the plan launched in 2005 was largely successful.

15.5.7.5 Synthesis

The voluntary agreements have been successful particularly in countries with traditions of close cooperation between government and industry (IPCC, 2007; Rezessy and Bertoldi, 2011; Akimoto, 2012b; Yamaguchi, 2012).

Successful voluntary agreements are characterized by a proper institutional framework. This consists of, first, capable and influential industrial associations that serve as an arena for information exchange and development of common expectation among industries. Second, governmental involvement in implementation review is crucial. Third, accompanying measures such as technical assistance and subsidies for energy audits and equipment can also be instrumental. Finally, regulatory threats, even if they are not explicitly articulated, are an important motivating factor for firms to be active in the voluntary agreements.

The key benefits of voluntary agreements are: 1) quick planning and actions when technological solutions are largely known but still face uncertainties; 2) flexibility in phasing technical measures; and 3) facilitating coordination and information exchange among key stakeholders that are crucial to removing barriers to energy efficiency and CO2 reductions. 4) providing an opportunity for "learning by doing" and sharing experiences.

However, several voluntary agreements have been criticized for not bringing about significant environmental impacts due to their limited scope or lack of proper institutional framework to ensure the actions to be taken (15.5.7.2; 15.5.7.3).

As cross-national evaluations, (Morgenstern and Pizer, 2007) reviewed voluntary environmental programs in the US, Europe and Japan and found average reductions in energy use and GHG emissions of approximately 5% beyond baselines. (Borck and Coglianese, 2009) argued that, as an alternative to regulatory approaches, voluntary agreements may effectively achieve small environmental goals at comparatively low cost.

The major role of voluntary agreements is to facilitate cooperation among firms, industrial associations and governments in order to find and implement low cost emissions reduction measures. Such a role is important because large mitigation potential exists, yet it is hampered by formidable barriers such as lack of information and coordination among actors. In such context the voluntary agreements can play an important role as part of a policy package.

15.5.8 Summary

This section has reviewed a range of policy instruments. Among the four policy evaluation criteria, literature is rich for economic and environmental effectiveness. The distributional incidence of taxes has been studied quite extensively, much less is known about other policy instruments. Political and institutional feasibility was also discussed as a design issue of economic instruments. The reasons for which sector specific policy instruments such as regulations and information measures have higher political feasibility than economy-wide economic instruments were briefly discussed in 15.2, but there is a dearth of literature really analyzing this issue.

Basic economics suggests that one instrument – e.g., a price on carbon – would be most cost effective in dealing with the market failure associated with the release of greenhouse gases. The presence of other market failures, however, means that one instrument is insufficient for dealing comprehensively with issues related to the climate problem. We have seen in 15.5.4 that there are cognitive and institutional factors that imply barriers to market response to carbon prices. Therefore, regulatory approaches, information programs, voluntary agreements and government provision, may serve as a complement to pricing policy as a way to remove barriers, thereby saving the money of firms and individuals and reducing social costs. There are strong separate arguments for a technology policy to correct for the externality implied by insufficient protection of property rights, as detailed in 15.6 below. Furthermore, because carbon pricing policy is often lacking or insufficient for political reasons in nations, various policy instruments are playing substitutive role (see 8.10 for example of transport sector).

In several sectors such as transport, urban planning and buildings, energy, and forestry, government planning and provision of infrastructure is important, even crucial, for achieving emission reductions in a cost-effective manner. Absent the appropriate infrastructure, the costs of achieving significant emission reduction might be prohibitive.

As discussed in 15.2 and this section, real-world politics tend to produce various policy instruments and differentiated carbon price across sectors owing to politics. Those policy instruments may positively interact as illustrated above, but it may negatively do, unfortunately. Such interactions will be further detailed in section 15.7 and 15.8. A policy maker is facing the challenge to understand how the policy package is constructed in her nation and harmonize various policy instruments so that they interact synergistically.

Box 15.2 National and Sub-national Policies Specific to Least Developed Countries

A number of developing countries have developed legislative and regulatory frameworks to measure and manage GHG emission (Box 15.1). These frameworks or strategies can be a part of larger development plans that aim to shift the economy to a low carbon and climate resilient trajectory. These plans can serve an important signaling function by aiding coordination of government agencies and stakeholders in addition to providing the government's commitment to a low-carbon policy framework (Clapp et al., 2010).

There are pre-requisites to develop these low carbon development strategies. Achieving this policy 'readiness' entails assembling the technical knowledge and analytical capacity, legal and institutional capacity, and engagement of stakeholders in the process (Aasrud et al., 2010; van Tilburg et al., 2011).Capacity building is also a continuous process that aims to improve strategies over time to enhance low carbon outcomes. Readiness for market-based instruments increases mitigative capacity in general and enables implementation and monitoring of mitigation policies (Partnership for Market Readiness, 2011). Due to tremendous variation in capacity across countries, sufficient flexibility to allow these strategies to evolve over time is needed (Clark et al., 2010; van Tilburg et al., 2011).

Evidence from CDM projects indicates that capacity building is necessary but not sufficient to allow countries to attract CDM projects. Targeted measures like support for Designated National Authorities have shown to be successful (Okubo and Michaelowa, 2010). In addition, CDM projects have been an important mechanism for creating awareness about climate mitigation, and have served as an indirect link between cap and trade systems around the world (Michaelowa, 2013). Some developing country beneficiaries of CDM are also moving towards implementing longer term national carbon mitigation policies. For an assessment of the Clean Development Mechanism, please refer to Chapter 13 (13.13.1.2) and Chapter 16 (16.8) for the technology component.

Climate mitigation has also been pursued through a co-benefits approach (See 15.2). Increasing access to energy services is an important priority for policymakers in developing countries (Chapter 4). 1.4 billion of the world's people have no access to electricity and roughly 3 billion lack access to clean fuel for heating and cooking (Pachauri et al., 2012, p. 19; IEA/OECD, 2013).In the short term, policies may address use of climate-friendly technologies like solar lighting alternatives to kerosene lamps (Lam et al., 2012), and gasifier cook stoves (Grieshop et al., 2011), while longer term policies may address more comprehensive approaches such as universal grid connectivity. Chapter 6 (Section 6.6.2.3) and Chapter 16 (Box 16.3 in Section 16.8) use global scenario results to conclude that universal basic energy access can be achieved without significantly increasing GHG emissions.

One option particularly relevant for developing countries is a repeal of regressive subsidies given to fossil-fuel based energy carriers, together with suitable compensating income transfers so as not to limit energy access or increase poverty (see 15.5.2). In some developing countries, subsidies to fossil fuels are slowing penetration of less expensive renewables. For example subsidies to natural gas result in an incremental levelized cost of wind power in Egypt of an estimated 88% (Schmidt et al., 2012). Care must also be taken to ensure transparency and to clearly demonstrate that the savings that accrue from the removal of subsidies will be used to benefit the poor.

15.6 Technology Policy and R&D Policy

15.6.1 Introduction

As discussed in Chapter 3.11, there are market failures associated with research, technology development and technology diffusion that are distinct from and interact with the market failures associated with environmental harm of human activities such as anthropogenic climate change. There is therefore a distinct role for technology policy in GHG mitigation, which is complementary to the role of policies aimed directly at reducing current GHG emissions, which are discussed in Section 15.5 above.

Public policies and institutions affect the rate and direction of technological change at all points in the chain from the invention, to innovation, to adoption and diffusion of the technology, and unaddressed market failures or barriers at any stage in the chain can limit policy effectiveness (Nemet, 2013).The innovation systems literature stresses that technology development and deployment are driven by both technology push (forces that that drive the development of technologies and innovation such as R&D funding, tax breaks for R&D, patents), and demand pull forces that increase the market demand for technologies such as technology subsidies and standards (Gallagher et al., 2012; Wilson et al., 2012).

Technology systems may create path dependencies in the innovation process. The current dominance of the carbon-based system creates incentives to improve carbon technology rather than non-carbon. This has been observed in private (Aghion et al., 2012) as well as public institutions (Unruh, 2000) exemplified by fossil fuel subsidies (OECD, 2013). Escaping carbon lock-in is essentially a problem of co-ordination (Rodrik, 2007; Kretschmer, 2008), which can be facilitated by public policy that addresses technology-push, demand-pull and framework conditions in a complementary fashion (Nemet, 2013).

This subsection addresses the generic issues that arise in the implementation of policies intended specifically to foster the development and implementation of low-GHG technologies. It begins by discussing technology policy instruments in three overarching categories: 1) the patent system and other forms of intellectual property ("IP"); 2) public funding of research, tax subsidies for firms engaging in Research and Development ("R&D"); and 3) various policies designed to foster deployment of new technologies. It then moves on to discuss the impact of environmental policy on technological change in general, technological change in a broader social framework often termed an 'enabling environment' together with interactions across various elements of innovation systems, and finally the importance of incorporating program evaluation into the design of technology policy

15.6.2 Experience with Technology Policy

15.6.2.1 Intellectual Property

Public policy towards intellectual property inherently involves a trade-off between the desire to create incentives for knowledge creators and developers, and the desire to have new knowledge used as widely as possible once it is created (Hall, 2007). It is therefore crucial to analyse the extent to which IP protection such as patents, will foster climate change mitigation, by encouraging the creation and development of new GHG-reducing technologies, versus the extent to which it will hamper mitigation by raising the cost and limiting access to such new technologies as are developed. IP policy will affect climate mitigation both through its effects on the creation of new technology and on the international transfer of mitigation technology. The first of these mechanisms will be considered here; the effect of IP policy on technology transfer is discussed in Chapter 13.9.

In general, the empirical evidence that IP protection stimulates innovation is limited to the chemical and pharmaceutical sectors, and to developed economies (Park and Ginarte, 1997). It is unclear to what extent IP protection is relevant to the development of the kind of technologies that would mitigate climate change in advanced and middle income countries, and it appears unlikely to be relevant to indigenous technology development in the poorest countries (Hall and Helmers, 2010).[13]

The Trade Related Intellectual Property Rights ("TRIPS") agreement generally commits all countries to create and enforce standard IP protections, but it does allow for the possibility of exceptions to standard patent regulations for public policy reasons (World Trade Organization, 1994).Hence a major policy issue related to climate change is the extent to which developing countries will be compelled within the TRIPS framework to enforce strong IP protection relative to GHG-reducing technologies, or whether an exception or exceptions will develop for these technologies on public policy grounds (Derclaye, 2008; Rimmer, 2009).

Because the evidence that strong IP protection increases domestic innovation is almost entirely limited to specific sectors in the developed world, it is unclear whether maintenance of strong IP protection in less developed countries will increase those countries' indigenous creation or adaptation of GHG-reducing technologies. As discussed in Chapter 13, however, the evidence does suggest that the presence of an effective IP regime is a factor in fostering technology transfer into a country.

15.6.2.2 Public funding of research and development

Public funding of research and development may address specific market failures related to innovation (as discussed in Section 3.11), but may also help to compensate for barriers to private investment that may result from long lifetimes of incumbent technologies leading to lengthy transition times from one system/technology to another (Fouquet and Pearson, 2006; Fouquet, 2010), uncertainty about future levelized costs of capital or discount rates (Nemet, 2013), or the lack of guarantee on the success of an investment (Mazzucato, 2013; Nemet, 2013).

Public research expenditures that have the potential to foster the long-run development of GHG-mitigating technology come under a number of different common public research expenditure categories, including environment, agriculture, materials, and others. There are no widely accepted data that attempt to identify and sum up public expenditures across different categories that potentially relate to GHG-mitigation technologies. Much discussion about the potential for technological change to mitigate GHG emissions revolves around reducing and eliminating use of

[13] There are however other relevant examples for instance of indigenous knowledge in developing countries being valuable when it comes to biodiversity and pharmaceuticals.

fossil fuels, and the largest single category of public research expenditure related to mitigation is energy research, discussed in Section 7.12.2.

Public energy-related research expenditures among the IEA countries currently comprise about 5% of total public R&D spending in those countries, less than half the share of such research in total public research spending in 1980. Gallagher et al (2012) report an increase in public funding for energy-technologies among IEA member countries in the 2000s but also find a continued prominence of funding for nuclear and fossil fuel technologies. A similar trend has been noted for non-IEA members like Brazil, China India, Mexico, Russia and South Africa (Gallagher et al., 2012). A gradual but steady increase in this share is a major policy option for fostering the long-run development of GHG-reducing technologies (Jaffe, 2012).

The U.S. National Research Council evaluated Federal Energy RD&D investments in energy efficiency and fossil energy for the period 1978-2000. The NRC found that these investments “yielded significant benefits (economic, environmental, and national security-related), important technological options for potential application in a different (but possible) economic, political, and/or environmental setting, and important additions to the stock of engineering and scientific knowledge in a number of fields” (U.S. National Research Council, 2001). In terms of overall benefit-cost evaluation, the NRC found that the energy efficiency programs produced net realized economic benefits that “substantially exceeded” the investment in the programs. For the fossil energy programs, the net realized economic benefits were less than the cost of the programs for the period 1978-1986, but exceeded the cost of the programs for 1986-2000 (U.S. National Research Council, 2001). Japanese technology RD&D programs for renewable energy and energy efficiency, known as Sunshine program and Moonlight program since 1974, were also found to be both economically and environmentally effective (Kimura, 2010).

In the short run, the availability of appropriately trained scientists and engineers is a constraint on a country’s ability to increase its research output (Goolsbee, 1998) (See also Jensen and Thomson (2013)). This factor combines with short-run adjustment costs in laboratory facilities to make rapid ramp-up in research in a particular area likely to be cost-ineffective, as found to occur, for example, as a result of the doubling of U.S. health research (Cockburn et al., 2011). Therefore, sustained gradual increases in research are likely to be more effective than short-run rapid increases. In the long run, it is possible to expand the supply of scientific and technical labour available to perform energy-related research. This can occur through training that occurs when publicly funded research is carried out at universities and other combined research and teaching institutions, and/or via direct public funding of training. Success at increasing the technical workforce has been found to be a crucial factor in the long-run benefits of health-related research in the U.S. (Cockburn et al., 2011).

15.6.2.3 Policies to foster or accelerate deployment and diffusion of new technologies

In addition to fostering technology development through research, many policies seek to foster the deployment of GHG-mitigating technologies in households and firms. Such deployment policies could be thought of as a form of abatement policy, to the extent that they reduce emissions relative to what would occur with the use of previous technologies. But the more fundamental reason for public policy to foster technology deployment is that deployment feeds back and enhances subsequent improvement of the technology over time (Jaffe and Stavins, 1994; Henkel and Hippel, 2005; Jaffe, 2012). For example, publicly funded research certainly played a role in the digital revolution, but active government involvement as an early purchaser was also crucial (Mowery, 2011). Purchases were made of products meeting stated technical specifications, and this approach has helped move products down the learning curve, eventually allowing civilian versions to be sold competitively.

Market failure in the deployment of new technologies is often illustrated via an image of a ‘Valley of Death’ between small scale or prototype developments and successful commercialization, in which the need for substantial increase in the scale of investment combines with uncertainty about technical reliability, market receptiveness and appropriability to stall or slow deployment (Grubb, 2004; Nemet, 2013, p. 112). A variety of demand-pull public policies can operate to carry technology deployment through the Valley of Death.

As laid out in Table 15.2 economic instruments such as subsidies, regulatory approaches, information programmes, government provision of public goods and services, as well as voluntary actions are common across sectors. The targeted technologies include low-emission vehicles such as hybrid cars in the transport sector (8.10), efficient electric appliances such as LED in the building sector (9.10), and advanced industrial equipment (11.10). Feed-In-Tariffs are used for renewable in power sector (7.10). Quantity requirement are also common, including Renewable Portfolio Standards in power sector (7.10), biofuel mandates in transport sector (8.10). Information programmes such as labeling of home electric appliance may be used to promote the sales of new, low emission technologies (9.10).

Since AR4, a large number of countries and sub-national jurisdictions have introduced support policies for renewable energy. These have promoted substantial diffusion and innovation of new energy technologies such as wind turbines and photovoltaic panels, though many RE technologies still need policy support, if their market shares are to be increased (7.5.3, 7.6.1, 7.8.2, Chapter 11 Bioenergy Annex).

Chapter 7 (citing the SRREN) argued that "...some feed in tariffs have been effective and efficient at promoting RE electricity, mainly due to the combination of long-term fixed price or premium payments, network connections, and guaranteed purchase of all RE electricity generated". Feed-in-tariffs have been effective in promoting renewables in Germany and other nations (Couture and Gagnon, 2010; Ragwitz and Steinhilber, 2013). It is also argued that the flexibility of FITs can incorporate economic and technological changes (Klobasa et al., 2013); encourage dynamic innovation (Mitchell et al., 2006). Proving dynamic efficiency in the narrow economic sense is more complicated, although Jaffe et al, (2005) have explored this in a somewhat positive light.

There are different views on FITs, especially in relation to their cost-effectiveness. Some criticize FIT of having 'failed to harness market incentives' because it is not statically cost effective (ie it supports photovoltaics in addition to wind energy, although the former is more expensive than the latter) (Frondel et al., 2010) (2008)). Schmalensee (2012) using a simple model argues that while FITs shift risk away from investors in renewable energies, they may not reduce the risk to society as a whole. In a paper for the European Union (Canton and Lind�n, 2010). Canton and Linden argue that feed-in premiums are preferable to feed-in tariffs if internal market distortions are to be avoided.

With the increasing market shares of intermittent generation, new challenges have to be addressed in respect to grid and market integration such as capacity constraints, demand spikes, back up capacity and transmission. A reform of market design, including flexible demand side pricing, is proposed to make the system more flexible so it can react to the new challenges. (See 7.10 and SSREN chapter 8 for details (Sims et al., 2012)).

A theme that runs through many of the sectoral deployment policy discussions is the importance of information, and the relationship between incomplete information and risk. Uncertainty about the physical and economic performance of new technologies is a major factor limiting their diffusion, so policies that address information issues may be complementary with economic incentives or regulatory approaches.

Many nations, including Germany, Spain, China, India, among others, have implemented ambitious deployment programs for renewables consisting of capacity targets, FIT, and so forth (Jänicke, 2012), resulting in rapid capacity expansion and lower costs of technologies. . Such progress may result in economic and environmental efficiency in the long run at the global scale (Kalkuhl et al., 2013). Ondraczek (2013) identifies awareness among consumers as a critical element in market development in Kenya and Tanzania and finds evidence for a "virtuous cycle" between dissemination and awareness. Friebe et al. (2013) emphasize the need for including pre and post-sales services to sustain the uptake of solar home systems. (Glemarec, 2012) highlights the role for public-private partnerships to deliver energy access but underlines the need for public investment in capacity and market development.

Many developing countries face a somewhat different set of choices in encouraging technology deployment because of the dominance of state-owned or other monopoly enterprises in the energy sector. (Liu and Kokko, 2010) evaluate the factors related to the significant growth of wind power in China, and conclude that administrative rules stipulating levels of wind usage have been more effective than incentives operating through the pricing system. (Pegels, 2010) describes the introduction of a renewable FIT guaranteed for 20 years in South Africa, but notes that it is unclear what effect this will have on the investment decisions of the monopolist electricity supplier.

15.6.3 The impact of environmental policy instruments on technological change

There is some empirical literature assessing the impact of generic environmental policy instruments (discussed in the previous subsection) on technological change. For surveys, see (Newell, 2010) and (Popp, Newell, et al., 2010a). (Jaffe and Palmer, 1997) looking across industries in the U.S., found that more stringent regulation was associated with higher R&D expenditures (controlling for industry fixed effects), but did not find any impact on industry patents. Lanjouw and Moody (1996) did find that across the U.S. Germany and Japan, patenting rates were correlated at the industry level with pollution control expenditures.

A number of studies have looked at the impact of energy prices on energy-saving technological change. These effects can be seen as indicative of the possible consequences of GHG policies that increase the effective price of emitting GHG. (Popp, 2002) found that rising energy prices increased the rate of patenting with respect to alternative energy sources and energy efficiency, with more than one-half the effect coming within five years of energy price changes. (Newell et al., 1999) found that rising energy prices increased the efficiency of the menu of household appliances available for purchase in the U.S. The Norwegian carbon tax appears to have triggered technology innovation in the form of carbon sequestration in the Sleipner gas field (Sumner et al., 2011a). Fuel taxes moved auto industry innovation towards more efficient technologies (Aghion et al., 2012), and the EU ETS moved the firms most affected by its constraints towards low-carbon innovation (Calel and Dechezleprêtre, 2012).

At a theoretical level, there are arguments why incentive-based policies such as carbon taxes or tradable permits are more conducive to innovation than regulatory approaches (Popp, Newell, et al., 2010b). After the 1990 Clean Air Act Amendments in the U.S. implemented a tradable permit program for sulphur dioxide, (Popp, 2003) found that the rate of patenting on techniques for sulphur removal increased, and (Lange and Bellas, 2005) found that both capital and operating expenditures for scrubbers were reduced. In a survey of research on the effects of tradable permit systems on technology innovation and diffusion, (Bellas, 2011) concluded "The general result is that tradable permit programs have improved the pollution control technology compared to the previous regulation used." Sterner and Turnheim (2009) find similarly that the very high fee on NOx in Sweden has led to a rapid process of both innovation and technology diffusion for abatement technologies.

More recently, a few studies have explored the effect of renewable energy policies on energy innovation. (Johnstone et al., 2010) found that policy had a significant impact on patent applications for renewable technologies, with different policy instruments being effective for different technologies. (Popp, Hascic, et al., 2010) found that the link between greater patenting and investment in specific technologies is weak, but there does seem to be an association between policy and investment.

15.6.4 The social context of technological transitions and its interaction with policy

The central insight from the empirical literature is that both technology push and demand pull policies are required to be most effective (Nemet, 2009). A 'virtuous cycle' (IEA, 2003; Edenhofer et al., 2012) can occur, derived from learning from combined technology push and market pull whereby as 'learning' from market demand feeds back in to research and development, the improved product leads to more market demand and reducing costs. This virtuous technology and market cycle has been extended to include a third cycle of policy learning (Jänicke, 2012) whereby as learning from a successful policy occurs across the innovation chain, it can also be fed back into the process.

A technology policy will be more effective if it addresses multiple aspects such as institutions, regulations and standards, political models, laws, social norms and preferences, individual behaviours, skills and other characteristics. This idea was originally developed and encapsulated in the UNFCCC definition of an 'enabling environment' (UNFCCC, 2001).[14] This general intention to match up specific technology requirements with the system situation in which they develop has been called framework conditions (Grubb, 2004), enabling environment (Edenhofer et al., 2012; Johansson et al., 2012), enabling factors (Nemet, 2013), and complementary innovations (Grubb et al., 2014).

There is a literature base that explores technology transitions and the implications of multilevel interactions across social and technological elements (e.g. (Geels, 2011; Meadowcroft, 2011; Foxon, 2011). Three social challenges are raised as especially salient to social management when attempting to alter the technological system: (1) the size and visibility of transfers and assets created; (2) the predictability of pressure to expand the focus of the policies to broaden the social benefits; and (3) the potential for market incentives and framings of environmental issues to undermine normative motivational systems (Parson and Kravitz, 2013). Managing these social challenges may require innovations in policy and institutional design, including building integrated policies that make complementary use of market incentives, authority and norms (Foxon, 2011; Gallagher et al., 2012; Parson and Kravitz, 2013). Doing so will reduce the risk of market incentives failing to achieve behavioural change and recognizes that incentives and norms have to be integrated to achieve sustainability transitions.

15.6.5 Building program evaluation into government technology programs

Evaluation of government programs to foster new energy technologies has been hampered by a lack of complete and consistent evaluation data at the program level (U.S. National Research Council, 2001). This problem is common to many government technology programs. Proper evaluation requires that data on project selection and project performance be collected as programs commence and maintained after they are completed (Jaffe, 2002). Wider use of such evaluation methods would allow experience with relative effectiveness of different programs to be used to improve outcomes over time. While the above argument applies to all governmental policy in general, it is particularly important for technology development programs that may be vulnerable to governmental failure related to the picking and choosing of technologies under high uncertainty (Helm, 2010).

[14] Enabling environment is defined as: "the component of the framework [that] focuses on government actions such as fair trade policies, removal of technical, legal and administrative barriers to technical transfer, sound economic policy, regulatory frameworks and transparency, all of which create an environment conducive to private and public sector technology transfer" (UNFCCC, 2001).

15.6.6 Conclusion

There is a distinct role for technology policy in GHG mitigation. This role is complementary to the role of policies aimed directly at reducing current GHG emissions. (15.6.1)

The availability of new technologies is crucial for the ability for realistically implementing stringent carbon policies. Technology policy will be most effective when all aspects of the innovation/deployment chain are addressed in a complementary fashion (15.6.1). Investment depends on the willingness of a variety of actors to manage the balance between the risks and rewards in each step of the chain, and government decisions are crucial to this balance.

Evidence suggests that the presence of an effective IP regime increases domestic innovation. However, as evidence is almost entirely limited to specific sectors in the developed world, it is unclear whether strong IP protection in less developed countries will increase those countries' indigenous creation or adaptation of GHG reducing technologies (15.6.2.1).

Worldwide investment in research in support of GHG mitigation is small relative to overall public research spending. The effectiveness of research support will be greatest if it is increased steadily rather than dramatically or erratically (15.6.3).

A wide range of policy approaches is prevalent across sectors, which enable policy design that addresses sector- and technology-specific attributes. These policies are often designed as complementary sets of policies, or policy packages. (15.5.1 and 15.6.2.3)

Complementary framework conditions, or an enabling environment, may complement a package of technology-push and demand-pull policies (15.6.4). Managing social challenges of technology policy change may require innovations in policy and institutional design, including building integrated policies that make complementary use of market incentives, authority and norms (15.6. 4).

It is important that data collection for program evaluation be built into technology policy programs (15.6.5), because there is very little empirical evidence on the relative effectiveness of different mechanisms for supporting the creation and diffusion of new technologies.

15.7 Synergies and Trade-offs among Policies

15.7.1 Introduction

This section discusses interactions between policies with different main objectives as well as between differing climate policies with the same objective. Subsection 15.7.2 discusses relationships between policies with different principal objectives – for example, between climate policy and development policy. The next two sections consider interactions between climate policies. Subsection 15.7.3 describes interactions between different climate policies at different levels of government, and 15.7.4 takes up interactions between climate policies enacted at the same level of government. The interactions in 15.7.3 and 15.7.4 reflect the absence of policy coordination, and they affect the environmental and economic outcomes. Deliberate linking of policies is discussed in the next section, 15.8.

15.7.2 Relationship between policies with different objectives

Governments throughout the world have enacted various policies to support the mitigation of climate change, which is the central objective of climate policy. However, the implementation of mitigation policies and measures can have positive or negative effects on additional objectives – and vice versa. To the extent these side-effects are positive, they can be deemed 'co-benefits'; if adverse and uncertain, they imply risks.[15] The co-benefits of climate policy are primary benefits of policies with other main objectives. Social development is a primary benefit of development policy, since such development is the main objective. Similarly, enhanced energy security, technological development, and reduced air pollution are primary benefits of energy security, technological development, and air-pollution policies, respectively. To the extent that these other policies (with other objectives) lead to mitigation, such mitigation is a co-benefit of these other policies.

Although there is growing interest in research on mitigation as a co-benefit (see sections 1.2.1 and, e.g., Kahn Ribeiro and de Abreu, (Kahn Ribeiro and de Abreu, 2008)), the great majority of the literature assessed in other chapters focuses on the co-effects of sectoral mitigation measures (section 7.9, 8.7, 9.7, 10.8, 11.7, 11.13.6, 12.8) or mitigation pathways (6.6) on additional objectives.[16] Table 15.1 in section 15.2.4 provides a roadmap for the assessment of those co-benefits and adverse side effects on the many objectives examined in various chapters of this report and highlights that the effects on energy security and air pollution as well as the associated health and ecosystem impacts are discussed in all sector chapters. For example, stringent mitigation results in reduced combustion of fossil fuels with major cuts in air pollutant emissions significantly below baseline scenarios (see 6.6.2.1 and, e.g., (ApSimon et al., 2009) for a discussion of policy interaction in Europe); by increasing the diversity of energy sources and reducing energy imports in most countries, mitigation often results in energy systems that are less vulnerable to price volatility and supply disruptions (see 6.6.2.2 and, e.g. (Lecuyer and Bibas, 2011) for a discussion of policy interaction in Europe).

According to recent scenario studies assessed in section 6.6.2.7, stringent climate policies would significantly reduce the costs of reaching energy security and/or air pollution objectives globally.

There are two important advantages to coordinating separate policies and their various benefits. By coordinating policies, the various benefits and costs can be considered in an integrated fashion, which offers information helpful to determining how to achieve the objectives at low cost (see 6.6.2.7). In addition, coordinating policies can improve political feasibility. The concept of "mainstreaming" climate policy refers to the linking of climate policy with other policy efforts, particularly policy efforts that have broad recognition. The prospects for successful climate policy can be enhanced through such mainstreaming (Kok and de Coninck, 2007).

Development frameworks at international or national levels, or by sector, may include mainstreaming as a key element. For it to be effective, climate change mitigation needs to be mainstreamed in appropriate national and sector planning processes to widen development goals within national and sectoral contexts. For developing countries, such integration of mitigation into development planning can reduce problems of cooperation and coordination that may arise across different levels of government (Tyler, 2010).

Mitigation plans can be embedded in national policy-making processes to align economic and social development with mitigation actions. For example, in China, the National Leading Group on Climate Change is part of the National Development and Reform Commission, the principal national planning body (see 15.2.2.2).

Limited institutional capacity in developing countries presents the most significant barrier to mainstreaming of mitigation policies. This includes a lack of knowledge and/or expertise in climate

[15] Co-benefits and adverse side-effects describe effects in non-monetary units without yet evaluating the net effect on overall social welfare. Please refer to the glossary in Annex I for definitions and to sections 3.6.3 and 4.8 for a discussion of how the concept of co-benefits relates to welfare and sustainable development, respectively.

[16] Recent literature assessed in sections 6.6.2.3, 7.9.1 and 16.X finds that increasing access to modern energy services may not conflict with mitigation objectives – and vice versa.

change issues, a lack of (or weak) oversight and/or enforcement. Developing countries aiming to mainstream and implement climate change mitigation policies must; 1) encourage awareness on the topic; 2) establish related training programs; 3) ensure an adequate level of finance for enforcement; and 4) enhance coordination between ministries (Ellis et al., 2009).

15.7.3 Interactions between climate policies conducted at different jurisdictional levels

Climate policy has been conducted at various jurisdictional levels: international, national, regional (state or provincial), and local (municipal). Important interactions can occur across jurisdictional levels. Some interactions are beneficial, reinforcing the intended effects. Others are problematic, interfering with the planned objectives. Sound policy making requires attention to these interactions.

15.7.3.1 Beneficial interactions

Policies introduced by a local jurisdiction sometimes reinforce the goals of efforts undertaken at a higher jurisdictional level. In particular, a sub-national policy can enhance cost-effectiveness if it addresses market failures that are not confronted by a national climate policy. Thus, for example, as seen in 15.5.4 and 15.5.6, an RPS in the electricity sector and an R&D subsidy could usefully complement a national emissions pricing policy.

The connections between instruments that deal with climate change and those that deal with congestion or local pollution also present an opportunity to policy makers, but they are very different since the latter vary depending on the socioeconomic context, technology, fuel and vehicle use (Parry et al., 2007; Oikonomou and Jepma, 2008; Vanderschuren et al., 2010; Parry, 2013). For example, urban planning implemented jointly with fuel or carbon taxes can help fast growing developing countries minimize resource waste by avoiding urban sprawl. Policies incentivizing more dense urban architecture combined with the appropriate infrastructure for modern public transport can be an important complement to energy taxation. Such policies can be supported (and possibly financed) by fuel taxes if the policy maker wants to discourage citizens from making private decisions that are incompatible with this broader vision; policy combinations for this sector are discussed in greater detail in Chapter 8. Conversely, subsidising fuels and taking a hands-off urban planning approach can result in urban sprawl and a growth in private automobile use along with growth in resulting emissions.

Local-level action can also be a good source of information by allowing experimentation. In the United States, environmental policies by the federal government have a history of evolving out of successful policy "experiments" undertaken by states (Goulder and Stavins, 2011; Shobe and Burtraw, 2012). Thus, an appealing feature of local-level actions are their ability to try out policy options not currently in place at the higher jurisdictional level; the higher jurisdiction may have more confidence in introducing a policy subsequently if it already has a successful track record at the more local level.

Finally, local policies can produce beneficial strategic interactions. If national policy is insufficiently stringent, a stringent state/province or even municipal policy may create pressure on the national government to increase its own policy's stringency. (Goulder and Stavins, 2011) cite the example of California, which repeatedly increased the stringency of its local air pollution standards and was repeatedly followed by the Federal government increasing Clean Air Act regulations' stringency. Similarly, (Lucon and Goldemberg, 2010) note the importance of Sao Paulo's GHG-reducing policies in influencing other local and even regional governments in Brazil.

15.7.3.2 Problematic interactions

Policies introduced at different levels sometimes interact in ways that compromise or weaken the intended environmental or economic impacts.

On particular difficulty that may arise is the problem of emissions leakage. This can occur, for example, when a climate change policy introduced at a lower jurisdictional level is "nested" within a cap-and-trade program implemented at a higher jurisdictional level. Consider the case where a cap-and-trade program exists at the national level, and where a subnational authority introduces a new policy intended to reduce its own (subnational) emissions beyond what would result from the national program alone. The subnational jurisdiction's efforts might indeed yield reductions within that jurisdiction, but facilities in other subnational jurisdictions covered by the cap and trade program will now use these allowances leading to higher emissions in these jurisdictions completely compensating the abatement effort in the more stringent jurisdiction. Since overall emissions at the higher level are determined by the given national-level cap, the effort by the sub-national jurisdiction does not succeed in reducing nationwide: it just causes emissions leakage – offsetting increases in emissions elsewhere in the nation. The national cap effectively prevents sub-national jurisdictions from achieving further emissions reductions (Goulder and Stavins, 2011; Shobe and Burtraw, 2012).

The issue applies to the United Kingdom's efforts to reduce emissions through a carbon tax on the power sector (electricity generators). The generators are require to pay the tax on every unit of carbon emissions while also being subject to the EU ETS cap on overall emissions. While the tax may lead to greater reduction in carbon emissions by the generators in the UK, the impact on overall emissions in the EU might be negligible, since overall European emissions are largely determined by the Europe-wide cap under the EU ETS. On this, see (Böhringer et al., 2008; Sartor and Berghmans, 2011; Goulder, 2013)

This leakage problem can be avoided when the lower-level jurisdiction's program is nested within a carbon tax program, rather than emissions cap, at the higher level. In this case, the subnational policies generally are not environmentally irrelevant. The reduced emissions in the subnational jurisdiction do not lead to a fall in the emissions price (the carbon tax) at the national level; hence there are no offsetting increases in emissions in jurisdictions outside the jurisdiction introducing the more stringent policy (De Jonghe et al., 2009; Fankhauser et al., 2010; Goulder and Stavins, 2011). This can be an important advantage of a carbon tax over a cap-and-trade system.

15.7.4 Interactions between policies conducted at the same jurisdictional level

Interactions also can arise when different policy instruments are introduced at the same jurisdictional level. These interactions can be beneficial or problematic in terms of the cost-effectiveness of reducing greenhouse gas emissions.

15.7.4.1 Beneficial interactions

The potential for cost-reducing interactions is greatest when the different instruments address different market failures. A fundamental principle of public policy is that the most cost-effective outcome results when there are as many policy instruments as the number of market failures involved, with each instrument focusing mainly on a different market failure (Tinbergen, 1970) .

Climate policy is meant to address one market failure in particular – the climate-change-related externalities associated with GHGs. As seen in 15.6, another important market failure applies in the market for innovation: because new knowledge can spill over to third parties, innovators often cannot capture all of the social benefits from the new knowledge they create. Introducing two policy instruments, for example, emissions pricing to address the emissions externality, and a subsidy to

R&D to address the innovation market failure, can lower the costs of achieving given emissions reductions. In addition to helping reduce emissions by encouraging fuel-switching and a reduction in demand, emissions pricing can help spur innovation. Likewise, the R&D subsidy can promote invention of low-carbon technologies, thereby helping to curb emissions. Hence the interactions of the two policies are beneficial. Although each of the two policies might to some degree affect both of the market failures, emissions pricing is particularly well focused on the first, while the R&D policy sharply addresses the second. Using two instruments helps achieve emissions reductions at the lowest cost. In this connection, (Fischer and Newell, 2004) and (Oikonomou et al., 2010) find that a policy combination including a price on GHG emissions and renewable energy subsidies achieves emissions reductions at significantly lower cost than either of these policies alone. (Schneider and Goulder, 1997) obtain a similar result for the combination of carbon tax and R&D subsidy.

As noted already in Subsection 15.5.4.1, several studies (Greene, 1998; Goulder and Parry, 2008; Gillingham et al., 2009b) argue that there is a market failure associated with consumer purchases of durable energy-using equipment (automobiles, refrigerators, etc.), according to which consumers systematically underestimate their own future gains from purchasing more energy efficient durables. To the extent that this market failure is significant, the combination of emissions pricing and a second instrument (for example, an energy-efficiency standard for appliances) to address this additional market failure could lead to beneficial interactions and promote cost-effectiveness.

Some studies suggest a market failure associated with reliance on crude oil, claiming that reliance on oil produces an "economic vulnerability externality," given the possibility of supply disruptions on the world oil market (Jones et al., 2004). Under these circumstances, the combination of emissions pricing (to address the climate change externality) and a tax on oil consumption (to address the vulnerability externality) can be a cost-effective way of dealing with both climate change and economic vulnerability. Several authors (e.g., (Nordhaus, 2009)) emphasize that the vulnerability to world oil price changes is largely a function of the share of overall oil consumption in GDP, rather than the share of consumed oil that comes from imports. This suggests that the vulnerability externality is best addressed through a tax on oil consumption rather than a tax on imported oil.

15.7.4.2 Problematic interactions

Multiple policies at the same jurisdictional level also can yield problematic interactions. This can happen when multiple policies only address the same market failure. Consider the situation where a given jurisdiction attempts to reduce greenhouse gases through both emissions pricing and another policy such as a performance standard (a limit on the ratio of emissions per unit of production). Economic theory claims that, absent market failures and other barriers, emissions pricing tends to promote a highly cost-effective outcome by promoting equality in the marginal costs of emissions-abatement across all the facilities that face the given price of emissions (the carbon tax or the price of emissions allowances). If, in addition, facilities face a performance standard, then this added policy approach either is redundant or it compromises cost-effectiveness.

It is redundant if meeting the performance standard would involve marginal abatement costs lower than the emissions price. In this event, cost-minimizing firms would be induced to meet or exceed this standard by the emissions price alone: there is no need for the standard. On the other hand, if the performance standard entails a cost per unit of abatement that is significantly higher than the emissions price, then this requirement sacrifices cost-effectiveness. Relying on emissions pricing alone would have promoted emissions reductions by the facilities that can achieve those reductions at the least cost. Thus it would likely have led to a situation where the more expensive technology approach was not employed. Hence in this case the combination of emissions pricing and the performance standard does not promote cost-effectiveness.

Emissions price policies interact with other policies differently, depending on whether the emissions price policy involves a quantity limit (as is the case under cap and trade) or a stipulated emissions price (as is the case under an emissions tax). In the presence of a cap-and-trade program, introducing an additional instrument such as a performance standard might yield no further reductions in overall emissions (Burtraw and Shobe, 2009; Fankhauser et al., 2010). The reason is that overall emissions are determined by the overall cap or number of allowances in circulation. The problem is formally very similar to the difficulty described in subsection 15.7.3 above, where in the presence of a national cap-and-trade program an effort by a sub-national jurisdiction to achieve further emissions reductions is likely to have difficulty achieving that goal. In contrast, introducing a performance standard in the presence of an emissions tax can in fact lead to a reduction in overall emissions. The price of emissions – the emissions tax – does not change when the performance standard causes a reduction in emissions. For this reason the reduction caused by the performance standard does not lead to a compensating increase in emissions elsewhere. Overall emissions fall.

For similar reasons, the same difficulty arises when a carbon tax is introduced in the presence of a cap-and-trade program at the same jurisdictional level (Fischer and Preonas, 2010).

Nevertheless, as suggested above, the combination of emissions pricing and some other policy could be justified in terms of cost-effectiveness to the extent that the latter policy directly addresses a second market failure that emissions pricing does not directly confront.

It is important to recognize that the notion of a "market failure" pertains only to the criterion of economic efficiency. Another important public policy consideration is distributional equity. Concerns about distributional equity can justify supplementing a given policy instrument with another in order to bring about a more equitable outcome. This may be desirable even if the multiplicity of instruments reduces cost-effectiveness.

15.8 National, State and Local Linkages

15.8.1 Introduction

In the last few years an increasing number of sub-national administrations across the world have been active in the design and application of climate change policies. Section 15.2 has reported some of these experiences, whereas Section 15.7 has dealt with some of the interactions that may arise with the simultaneous use of climate policy instruments by several jurisdictions. This section goes a little back and is basically interested in the allocation of climate policy responsibilities across the different levels of government that usually exist in most countries (central, provincial and local administrations). Although such allocation involves the use the policy types described in Section 15.4, the emphasis here will not be on instrument use in itself as this was already covered in Sections 15.5 to 15.7). The objective of this section is to examine the theoretical backing for such practical applications and to extract lessons that may be useful for future sub-national applications and even for the design and implementation of national and supra-national mitigation policies. When dealing with the reasons for and guidelines for the 'vertical' allocation of responsibilities among jurisdictions that co-exist in a country, the theory of fiscal federalism (economic federalism) offers valuable insights. In short, that the responsibility for public decision-making over a particular issue (e.g. allocation of public goods, economic stabilization, or distribution) should be given to the jurisdictional level that could better manage it. In this sense, fiscal federalism contends that the central government should have the basic responsibility for functions whose national extension would render ineffective and inefficient a sub-national approximation, including 'national' public goods (Oates, 1999).

15.8.2 Collective Action Problem of Sub-National Actions

Given the global and public good nature of climate change, its jurisdictional allocation should actually be at the highest possible level. A sub-global allocation, as observed in Chapter 13, would lead other jurisdictions that are not active in climate change mitigation to benefit without paying the costs, i.e. in a free-riding fashion (Kousky and Schneider, 2003). Empirically, case studies found that climate policies tended to be less intrusive at sub-national level. While co-benefits with local development were pursued, policies that might incur costs to local economy were avoided in prefectures in Japan (Aoki, 2010). The costs for a sub-national administration may be actually beyond those of pure mitigation, as climate policies implemented by a jurisdiction might bring about leakage, a 'horizontal' movement of economic activities to other jurisdictions without mandatory requirements (Kruger, 2007; Engel, 2009). Moreover, the 'reshuffling' that may be associated to sub-national policies may reduce their environmental effectiveness (Bushnell et al., 2008). As a consequence, climate change mitigation would be provided in a sub-optimal level with sub-national allocation of responsibilities.

15.8.3 Benefits of Sub-National Actions

Yet, even if the central government has a major responsibility in this area, this does not preclude the allocation of mitigation responsibilities within a federation, as observed in citizen's attitudes on this matter (Lachapelle et al., 2012). But even within the theory of fiscal federalism there are other reasons that may justify sub-national action in this field. First, as noted by (Edenhofer et al., 2013), the exploitation of heterogeneous sub-national preferences for mitigation would lead to efficiency gains. This is actually one of the reasons for the decentralization theorem, a centrepiece of fiscal federalism, which in fact justifies sub-national allocation of certain public goods.

Moreover, decentralization can contribute to policy innovation by providing an opportunity to experiment with different approximations. Indeed, there might be potential gains from learning by doing in policy terms without imposing large costs on an entire country or the world with untried options (Oates, 2002). Sub-national governments could also choose to be leaders in the development of climate policies to obtain potential economic gains that are associated to "first movers" (Jänicke and Jacob, 2004) and may provide guidance and incentives to other jurisdictions to follow them (Bulkeley and Castán Broto, 2012). Besides, as they tend to be smaller, sub-national governments may be able to adapt to new situations in a swifter manner and therefore may have a greater flexibility to modify existing climate change policies or to define new ones (Puppim de Oliveira, 2009; Galarraga et al., 2011).

Other general approaches to federalism, such as cooperative and democratic federalism, may also provide reasons for sub-national involvement in this area (Inman and Rubinfeld, 1997). On the one hand, cooperative federalism argues for allocating pure public goods to the local level, counting on the power of inter-jurisdictional bargaining to improve allocations. On the other hand, democratic federalism incorporates sub-national representation in central decision-making on public goods. In any case, federal structures may be crucial for the transmission of mitigation policies because most sub-national governments are now responsible for matters that have huge effects on GHG emissions: land use planning, building codes, waste management, traffic infrastructure and management, public transport, etc. (Collier and Löfstedt, 1997; Bulkeley and Betsill, 2005; Doremus and Hanemann, 2008). But sub-national governments also have direct policies aimed at GHG mitigation: energy efficiency programs, educational efforts, green procurement standards, partnership agreements with local businesses, or tree planting (Schreurs, 2008).

Yet another reason for a sub-national role in climate policies is beyond the standard collective action approach. By indicating that externality-correcting regulations and global agreements are not the only pace to tackling climate change problems, (Ostrom, 2010) suggested a polycentric approach in which mitigation activities are undertaken by multiple (public and private) units at diverse scales. The prevalence of sub-national actions in the field, contentious to other approaches, may be actually a proof of polycentrism in the area (Byrne et al., 2007; Sovacool, 2011). The polycentric approach could be seen as a reinterpretation of the findings of the federalism literature, as actions should involve many different agents in a reinforcing manner.

Finally, further issues may explain sub-national allocation. Local authorities, for instance, may be more effective in reducing GHG emissions from some sources such as waste and transport, as this may provide significant co-benefits to local citizens (Kousky and Schneider, 2003). Moreover, sub-central administrations are usually closer to the places and citizens impacted by climate change. Even though climate change is a global phenomenon, the nature of its impacts and severity varies significantly across locations so some sub-national governments have reasons to be more protective than national or supranational administrations (Andreen, 2008). This is also the case of adaptation, where sub-national authorities can better manage challenges such as flood risk, water stress, or "climate proofing" of urban infrastructure (Corfee-Morlot et al., 2009). In all the preceding situations, sub-national governments may tailor actions and policies to people's needs, with an easier identification of priorities and difficulties as they are closer to citizens than more centralized administrations (Lindseth, 2004; Galarraga et al., 2011).

15.8.4 Summary

As in other environmental areas (Dalmazzone, 2006), there is theoretical backing for the allocation of climate-related policies to sub-national levels of government, although there are several limiting factors to a widespread reliance on these administrations. A federal structure that provides coordination and enables an easier transmission of climate policies throughout the agents of the economy is likely to increase the effectiveness of actions against climate change. Moreover, the lessons learnt in the design and application of climate policies at different jurisdictional levels could be used in a global setting.

15.9 The role of stakeholders including NGOs

15.9.1 Introduction

This section considers the role of stakeholders and civil society in developing and delivering concrete climate mitigation action and focuses on how stakeholders impact policy design and implementation. The range of stakeholders is immense given the extent and complexity of climate change. Devising policy in an inclusive manner may be lengthy and politically challenging (Irvin and Stansbury, 2004), however adopting an inclusive approach to climate policy can bring advantages, notably through increasing the legitimacy of policy design, its durability and implementation (Lazo et al., 2000; Beierle, 2002; Dombrowski, 2010).

15.9.2 Advocacy and Accountability

Some of the major functions and roles of NGOs can include raising public awareness which often involves translating scientific and technical knowledge into actionable forms, lobbying, influencing business investment decisions, and monitoring and implementing agreements (Gulbrandsen and Andresen; Guay et al., 2004; Betsill and Corell, 2008; Newell, 2008; Dombrowski, 2010). Their domains of action also include engagement in sub-national and national policies and institutions as well as international processes like UNFCCC (Wapner, 1995; Lisowski, 2005). It is in these diverse forms that NGOs play a role in "connecting knowledge with responsibility" (Szarka, 2013) and promoting norms of accountability (Gough and Shackley, 2001; Newell, 2008).

Stakeholders can also affect when and how evidence of climate change translates into policies via the domestic political system (Social Learning Group, 2001). The differing results of the same scientific evidence, for instance, the political polarization in the United States versus more proactive and consensual attempts to find solutions in Europe (Skjærseth et al., 2013) demonstrate how stakeholder interests can filter scientific evidence.

Evidence also indicates that that some fossil fuel companies went further and promoted climate scepticism by providing financial resources to like-minded think-tanks and politicians (Antilla, 2005;

Boykoff and Boykoff, 2007), although other fossil fuel companies adopted a more supportive position on climate science (van den Hove et al., 2002a). Differences in the attitudes of oil companies towards climate change are explained in part by domestic institutional contexts and management structures as well as the structure of assets or technologies of different energy companies (Rowlands, 2000; Kolk and Levy, 2002).

15.9.3 Policy Design and Implementation

Three factors have been considered important for lobbying success in policy design namely: how institutions shape the space for participation (Kohler-Koch and Finke, 2007), organizational resources (Eising, 2007), and the policy environment (Mahoney, 2008; Coen and Richardson, 2009).

In the case of the EU ETS, Skodvin et al (2010) find that interest groups are able to limit "spectrum of politically feasible policy options." Instrument choice is a function of the extent of resources these interest groups control, the role of veto players in the political process, policy networks and entrepreneurs (Skjærseth and Wettestad, 2009; Skodvin et al., 2010; Braun, 2013; Skjærseth et al., 2013).

The role of business interests in supporting emissions trading as opposed to taxation, in the UK, has also been recognized (Bailey and Rupp, 2006; Nye and Owens, 2008). The political opposition to Australia's Carbon Pollution Reduction Scheme has been explained largely by the opposition of fossil fuel interests (Crowley, 2010, 2013; Macintosh et al., 2010; Bailey et al., 2012). Similarly, in New Zealand, the agriculture sector has played a major role in obtaining a transition period for the sector, use of an intensity-based accounting system, and free credits (Bullock, 2012). This has led to questions regarding the environmental effectiveness of the ETS (Bührs, 2008).

Stakeholders also affect policy durability, flexibility and implementation. For example, European Climate Change Programme featured consultation processes that ensured policy credibility by having the buy-in of stakeholders. Similarly, the persistence of climate legislation in California has been explained by the stability of coalition groups supporting the legislation due to path dependence despite the economic downturn in contrast to the emerging coalition at the national level which broke down after economic shocks (Knox-Hayes, 2012).

15.9.4 Conclusion

Early findings indicate the importance of institutions in creating spaces for stakeholder participation, the organizational resources of the stakeholders themselves, and the general policy environment as being critical factors that determine the effectiveness of stakeholder engagement. However, the degree to which policy design and implementation to mitigate climate change is dependent on stakeholder engagement is as yet under-researched and it must be stressed that the evidence base is thin and that these results primarily derive from case studies.

15.10 Capacity Building

As national and subnational governments around the globe confront the multifaceted challenge of climate change mitigation and adaptation, capacity is essential. According to the Agenda 21, building a country's capacity "encompasses the country's human, scientific, technological, organizational, institutional, and resource capabilities" (United Nations, 1992).

The priority for capacity building is strongly reflected in the Johannesburg Plan of Implementation (United Nations, 2002), where capacity building, especially for developing countries and countries with economies in transition, features prominently. It is also stressed in the UNFCCC's capacity building framework for developing countries (Decision 2/CP.7, (UNFCCC, 2001)). The goal of capacity building under this framework is "to strengthen particularly developing country parties, to promote the widespread dissemination, application and development of environmentally sound technologies and know-how, and to enable them to implement the provisions of the Convention. In addition, the COP under the UNFCCC requested the Subsidiary Body for Implementation to organize an annual in-session Durban Forum for in-depth discussion on capacity-building following COP-17" (Decision 2/CP.17, (UNFCCC, 2011)). The Durban Forum provides an opportunity for representatives from governments, UN organizations, intergovernmental and non-governmental organizations, academia and the private sector to share ideas, experiences, and good practices on implementing capacity-building activities.

15.10.1 Capacity to analyse the implications of climate change

Climate change is a severe and major problem that has the potential to seriously derail poverty alleviation in a number of low income countries (Dell et al., 2009). Climate change will affect livelihood assets by impacting health, access to natural resources and infrastructure (Skoufias, 2012). It is also likely to erode agricultural productivity in tropical climates (Skoufias, 2012). Given that the implications of climate change differ so dramatically between countries, to inform climate negotiations and allow countries to realize the full extent of their adaptation needs, substantial capacity would be required to analyze the implications of climate change and to formulate country positions. So far, the academic capacity is geographically very skewed. For example, the International Social Science Council commissioned a bibliometric study on social science research on climate change and global environmental change in the period from 2000 until 2010. It found that OECD countries completely dominated this research and that the poorest countries, notably in Africa, hardly were visible at all in the statistics (Hackmann and St Clair, 2012).

15.10.2 Capacity to design, implement an evaluate policies

The design, implementation, and evaluation of national and subnational climate change policies necessitate in-country human capital. National governments and civil society require that climate change policies be adapted to local economic, cultural, and social conditions to ensure their effectiveness and public support. To be politically acceptable, such work generally needs to be done by citizens of the country in which the policies are to be implemented. Political feasibility is mainly determined by policy design to improve environmental and economic effectiveness and distributional equity (Bailey and Compston, 2012c). A high level of scientific knowledge and analytical skills are required for such work. Capacity building allows the leadership to be sensitive to environmental constraints and encourages policy making to meet the needs of the people within these parameters (United Nations, 1992, p. 21).

Many studies analyse the technological options for achieving deep reductions in greenhouse gas (GHG) emissions however they do not necessarily reflect the need for capacity building. For example, while (Pacala and Socolow, 2004), through their 'stabilization wedges', increased the understanding of the technological options that could be deployed to reach stabilization targets, they did so without pointing out the capacity necessary to reach such a potential. These do however need local adaptation. Through the collaborative dialogue under the Durban Forum, key areas for capacity building on mitigation have emerged, including: low-carbon development strategies; Nationally Appropriate Mitigation Actions (NAMAs); Monitoring, Reporting and Verification (MRV); Technology Needs Assessments (TNAs); and mitigation assessments.

15.10.3 Capacity to take advantage of external funding and flexible mechanisms

Climate change, and the global policies to mitigate and adapt to it, also imply additional capacity challenges in order to take advantage of international funding and flexible mechanisms such as the Clean Development Mechanism (CDM) in the Kyoto Protocol, and REDD+ (Reducing Emissions From Deforestation and Forest Degradation). So far, the distribution of projects under flexible mechanisms has been very skewed towards countries with greater capacity. As an example, only 2.5% of normal CDM projects have been hosted by African countries (Fenhann and Staun, 2010).

In the preparations for the UNFCCC Durban Forum on Capacity Building (UNFCCC, 2011) it was noted that capacity-building in developing countries should be improved by (i) Ensuring consultations with stakeholders throughout the entire process of activities; (ii) Enhancing integration of climate change issues and capacity-building needs into national development strategies, plans and budgets; (iii) Increasing country-driven coordination of capacity-building activities; and (iv) Strengthening networking and information sharing among developing countries, especially through South-South and triangular cooperation.

15.10.4 Capacity building modalities

Capacity building is about equipping people, communities, and organizations with the tools, skills, and knowledge to address the challenges of climate change. It can be delivered through education, outreach, and awareness, but it can also be facilitated through peer learning, knowledge platforms, information exchanges, and technical assistance (Mytelka et al., 2012). The need for capacity building is large. Hundreds of thousands of scientists of various disciplines need to be trained globally in the coming decades as well as policy makers, civil servants, businessmen and civil society. These needs are not limited to developing countries, as it is needed at all levels of society and in all regions of the world.

There are many different modalities. Since COP-15, partnerships have formed at the international, national, and subnational level aimed at climate readiness activities. Capacity building in the private sector is also important. Studies indicate that good management, trained workers, and clean manufacturing increase energy efficiency while reducing CO2 emissions. Substantive carbon reductions can be achieved at zero or negative cost through improved workplace practices, optimized processes and behavioural changes in production (Bloom et al., 2010). Even this requires human resources and capacity to be undertaken.

Capacity building requires a long time horizon, and this is particularly evident in education-poor countries. Building in-country academic programs that can graduate well-trained masters and PhD students can take decades. When students graduate from such programs it takes an additional 5-10 years of post-doc and junior faculty positions to build the experience and skills to contribute at a high international level (Sterner et al., 2012). Capacity building initiatives are therefore fragile and require continued support and nurturing by both national governments and international organizations. This may be one additional and important area for climate finance.

15.11 Links to Adaptation

This section discusses links between national and subnational policies and institutions for mitigation and adaptation. Links between adaptation and mitigation policies at the international level are discussed in Chapter 13, while adaptation in general is discussed in WGII. Adaptation will be needed because some climate change is inevitable (Chapter 5). Indeed some governments have started to plan and implement policies aimed at tackling changes that are likely to take place or have taken place already (Aaheim et al., 2009). In the longer term, the level of adaptation needed will depend on the success of mitigation efforts and the resulting GHG concentrations, thus there is an obvious linkage between mitigation and adaptation. However, the level of adaptation needed will also depend on the climate response to any given GHG level, around which there is high uncertainty. Mitigation will help to reduce the uncertainty on future changes and is therefore helpful for planning adaptation.

It has been argued that mitigation and adaptation policies are related to each other (Smith and Olesen, 2010). This, however, is a controversial issue (Hamin and Gurran, 2009). Any given mitigation policy at the national or subnational level is unlikely to have a significant effect on the global climate, so that the climatic consequences of that policy for the purpose of planning adaptation can usually be ignored. The direct side effects of a mitigation policy for adaptation are more relevant. Examples of such direct effects are mainly in land use (discussed in 15.11.3 below) where synergies and tradeoffs between mitigation and adaptation policies may arise.

It is, of course, true that mitigation policies can have effects on adaptation across sectors. For example, carbon pricing can make air-conditioning more expensive, thus hindering adaptation to a warmer climate. However, this is simply one of many costs of a mitigation policy that will be taken into account while making policies. Conversely, adaptation to higher temperatures has led to increased electricity consumption for cooling (Gupta, 2012) that has to be taken into account while planning mitigation, but so do all changes in demand arising for other reasons such as income growth.

On the national scale, the approach to mitigation and adaptation differs between high or upper-middle income countries and low or lower-middle income countries due to the balance of responsibilities and the focus on mitigation versus adaptation.

The early national policy focus in high or upper-middle income countries was largely on mitigation. These policies were largely developed without in-depth consideration of adaptation linkages. Those high or upper-middle income countries that are developing national adaptation strategies and policies (e.g. see (Bizikova et al., 2008; Stewart et al., 2009; Bedsworth and Hanak, 2010; Biesbroek et al., 2010)) have shown limited consideration of the effects of adaptation policies on greenhouse gas emissions to date. Neufeldt et al (2010) investigated the reasons for this disconnect in Europe and found it was due to a strong sectoral separation: sectors that were major emitters have been mitigation focused, and have received little attention on adaptation, whereas climate sensitive sectors such as agricultural, although a potential contributor to emission reductions, have focused on adaptation. They also report that adaptation policy and actions have lagged behind mitigation more generally, and the difference in timing also contributes to the separation of the two domains. This is now starting to change: Bruin et al (2009) in the Netherlands considered the potential GHG emissions of adaptation measures as part of a national multi-criteria ranking of options.

To date, most of the national climate policy initiatives in low-income countries, especially in the Least Developed Countries, have focused on adaptation, notably through the National Adaptation Programme of Action (NAPAs). However, more recently there has been a shift with a number of national policy initiatives that aim to develop climate resilient, low carbon economies (also known as low-emission development strategies or green growth). These include Ethiopia's Climate Resilient Green Economy Vision (EPA Ethiopia, 2011) and Rwanda's Green Growth and Climate Resilience National Strategy for Climate Change and Low Carbon Development (Government of Rwanda, 2011). Given the importance of climate change in these highly vulnerable countries, these look to build climate resilience, but also recognise the benefits in advancing low carbon development. The linkages between emission reductions and adaptation in these studies are still at an early stage and most of the synergies between adaptation and mitigation are centred on the agricultural and forestry sectors.

Some local activities such as those regarding land-use decisions have important implications for both mitigation (e.g. by means of carbon sequestration) and adaptation (e.g. by means of increasing resilience to climate change). Ravindranath (2007) explores the synergies between mitigation and adaptation in the forestry sector. As forests are highly vulnerable to climate change, but provide opportunities for mitigation (e.g. through afforestation), efforts to enhance carbon sequestration need to embed adaptation elements so that exposure to climate impacts can be addressed. Mitigation efforts through forest management regimes such as conservation areas and sustainable forestry contribute to adaptation. Conversely, adaptation efforts such as urban forestry and measures to conserve soil and water also have mitigation effects (Ravindranath, 2007).

Similar issues have emerged for the agricultural sector, with the focus on climate-smart agriculture. This recognises the high vulnerability of agriculture, as a climate-sensitive sector, but also the fact that it is a major sources of greenhouse gas emissions in developing economies. A number of options have been identified as potentially beneficial for mitigation and adaptation, including (McCarthy et al., 2011) soil and water conservation (including conservation agriculture, low or minimum tillage, vegetation strips, terraces, structures such as bunds contours, shade trees, tied ridges, small-scale water harvesting, compost production, cover crops, improved fallows, crop residues), agroforestry, improved pasture and grazing management including restoration. These generally are based on sustainable agricultural land management (SALM) practices. These reduce climate related risks in the form of rainfall variability and soil erosion, increase soil organic matter and soil fertility, thus increasing productivity, and reduce emissions by either reducing soil emissions or preventing other more emission intensive activities. More traditional measures to increase productivity, such as fertiliser use or increased irrigation, have the potential to increase greenhouse gas emissions, e.g. because of the high energy intensity of fertiliser production, and the energy use in water abstraction and pumping, though they may still reduce land-use emissions by increasing the productivity and yields per hectare, and reducing future land-use pressures which may lead to deforestation (Chapter 11). However, as highlighted by McCarthy et al. (2011), many of these climate-smart options involve important opportunity or policy costs, higher risks, or may involve benefits that arise over longer time periods (e.g. improved soil function), or involve wider environmental benefits that are not immediately useful to farmers. They also frequently involve institutional, financial and capacity barriers, and so may not happen autonomously.

Both the forest and agricultural sectors also link through to issues of rural land-use change and land planning/management, which can have synergistic effects on mitigation and adaptation (Pimentel et al., 2010), but which can also involve complex trade-offs.

Overall, the emerging evidence suggests that while there may be a potential for synergistic mitigation and adaptation policy linkages in the agricultural and forest sectors, the translation of these policies through to implementation may well be challenging, because of the different characteristics of mitigation and adaptation (e.g. the global public good nature of mitigation versus the local benefits from adaptation), because of the additional costs involved (e.g. involving higher capital costs or opportunity costs associated with synergistic options), because of institutional, technological or behavioural barriers, and because different actors maybe involved in mitigation and adaptation decisions, including the need to address cross-sectoral aspects.

15.12 Investment and Finance

15.12.1 National and sub-national institutions and policies

The justification for investment and finance and the description of the various financial agreements have been elaborated in Chapter 13. Chapter 16 assesses in more detail the range of institutional arrangements for mitigation finance at the global, regional, national and sub-national levels. This section concentrates on institutional mechanisms which parties to the UNFCCC, developed and developing countries, have been using or introducing to facilitate, tap, channel, and catalyze climate change investment and finance. It also briefly touches on some of the major policy directions and trends affecting mitigation finance and investments. Earlier sections of this chapter presented the variety of policy instruments available and being used both in developed and developing countries. Public finance is needed for subsidies and public provision (Sections 15.5.2 and 15.5.6). In this section we track the consequences with a view to the aggregate funding needed.

Without dedicated financial policy, other policy instruments alone may be insufficient to mobilize the large scale investments needed to move the world away from its current high-emission path.

Recent case studies and some empirical evidence highlight the importance of targeted public finance to help catalyze and leverage private investment in some mitigation activities (CPI, 2012). For this purpose, governments have at their disposal a variety of mechanisms that include credit lines, bonds, guarantees, equity, venture capital, carbon finance, and grants (Maclean et al., 2008). These mechanisms exist and are effective mostly in developed and emerging economies (Kennedy and Corfee-Morlot, 2012).

In addition, a number of innovative mechanisms are being promoted in some developed countries with success. These include, 'property assessed financing districts' where residential and commercial property owners are provided with loans for renewable energy and energy efficiency, 'direct cash subsidies' to promote the installation of energy efficiency measures and renewable energy systems, 'power purchase agreements', and ESCOs – Energy Service Companies to implement performance-based energy efficiency projects (Ellingson et al., 2010).

National development banks are increasingly playing a critical role in leveraging public and private resources in both developed and developing countries. National development banks, which operate mainly domestically, have an advantage in accessing local financial markets and dealing with barriers that they understand better than others (Smallridge et al., 2013).

International financing for climate mitigation and adaptation has impacted the domestic climate discourse and has created incentives for sustainable development at national and local levels in developing countries (Metz and Kok, 2008). National and sub-national efforts to finance climate change often have an explicit link to international processes or support through the various mechanisms of the Convention and Kyoto Protocol or those encouraged to facilitate funding for developing countries such as bilateral and multilateral channels. Some of these mechanisms have led to significant investment in developing countries. An estimated USD 215.4 billion had been invested in 4832 Clean Development Mechanism projects by June 15, 2012 (UNFCCC, 2012). Similarly, the GEF estimates that since the start of its operations (1991-2013), it has leveraged over USD 27 billion for climate change projects (GEF, 2013).

A new trend is the establishment by several developing countries of funds and national funding entities dedicated to climate change. Table 16.2 lists some of these institutions, their objectives, governance, and sources of funding. The missions and objectives are diverse and their level of institutionalization varies from country to country. All are designed to tap and blend funding available from international and domestic sources – public and private -- to catalyze climate investment in their country (Flynn, 2011).

National funding entities have the potential to help countries cope with the proliferation of funds and entities offering financial resources for mitigation activities (Glemarec, 2011; Smith et al., 2011). Increased fragmentation of international assistance has increased transaction costs for recipients while the multiplicity and competitive nature of sources has challenged national and sub-national capacities (Knack and Rahman, 2007; Anderson, 2012). Limited absorptive and human capacity resources do however present serious challenges. Evidence of the ability of national funding entities to ensure coherence between national institutions dedicated to climate change and cabinet entities such as the Ministry of Finance or the Office of the President relies on case studies and, currently, does not yet offer general conclusions (Thornton, 2010).

15.12.2 Policy change direction for finance and investments in developing countries

There have been some significant trends in recent years regarding climate finance and the actors involved. Three are particularly relevant for their impact on the way climate finance is being managed and who does the management.

First, financing climate objectives by mainstreaming climate change into development planning has been gaining ground. This is particularly the case of countries wanting to integrate adaptation strategies into their overall national strategy as a way to build resilience. It is also evident in some of the climate change action plans and strategies of some countries that are clearly linked to poverty reduction and national development objectives (Garibaldi et al., 2013). However, the benefits and costs of integrating climate change considerations into development planning may be difficult to attain in practice. The OECD (OECD, 2005) warns of "mainstreaming overload" as climate change competes with other issues like governance and gender to be mainstreamed into development planning. Barriers to integrating climate and development objectives include: lack of human and institutional capacity and lack of coordination among line ministries (Knack and Rahman, 2007; Kok et al., 2008)

Second, is the growing recognition that financing climate actions can have large co-benefits. Investments in clean energy for example may result in improvement in health indicators as air pollution levels decrease. Similarly, investing in forest conservation may result in a reduction of GHG emissions from deforestation. Thus, the increasing interest in the concept of co-benefits or climate and development as "win-win" outcomes. Reducing emissions has been seen as a by-product of reducing energy costs in the case of China (Richerzhagen and Scholz, 2008b). REDD+ is seen as another major opportunity to deliver both emissions reductions and livelihood benefits. However, Campbell (2009) and Adams and Hulme (2001) argue that the ability to define these win-win objectives is a major factor for success.

Third, the number of actors involved in climate finance and investment is growing. Climate change finance is no longer a monopoly of the public sector. There is now a multiplicity of actors from the private and business world, whose level of financing exceeds that of the public sector several fold particularly in the middle-income and emerging economies (Gomez-Echeverri, 2013). This development has the potential to address implementation gaps, generate greater participation from stakeholders, and encourage public-private partnerships that promote sustainable development (Pattberg, 2010).

Two areas of need emerge from the literature (Cameron, 2011; Zingel, 2011). Attracting climate finance investments will require strengthening institutional and governance capacities at the national and sub-national levels in recipient countries. Specifically, the ability to formulate strategies and action plans, including policies and measures, formulate, assess and approve projects, demonstrate accountability and transparency to their own populations, as well as to the development partners to raise levels of investment confidence will be needed. In addition, robust mechanisms to ensure accountability are needed. This would involve greater transparency in both donor and recipient countries. The role of civil society organizations and the media could be strengthened for good governance and accountability.

15.13 Gaps in Knowledge and Data

- Cross-country comparisons of institutional design options, particularly mechanisms for coordinating and mainstreaming climate and other related sector policies, are limited. Wider use of evaluation methods would allow for the understanding of relative effectiveness of different options and designs to be used to improve outcomes over time.
- Evaluating the economic and environmental effectiveness of individual policy instruments and packages is difficult as various jurisdictions produce policy instruments influenced by context-specific factors such as co-benefits and political economy considerations. As a result, the cost of committing to a target and the actions needed to meet it, are difficult to estimate. For example, fuel tax in the transport sector is implemented for multiple purposes including energy security, congestion and pollution reduction, revenue for road construction, mitigation of climate change and so forth. It is very difficult to know how much mitigation efforts are made by "additional" carbon pricing compared to baseline.

- While the distributional incidence of taxes has been studied quite extensively, much less is known about the distributional incidence other policy instruments and packages. Similarly, knowledge gaps remain uneven across policy instruments on other criteria such as institutional, political and administrative feasibility.
- The asymmetry of methodologies regarding ”negative cost” policies regarding regulation and information measures with case studies arguing for negative private and social cost polices while critiques basing results on economic theory and models has meant that conclusive results are not yet available.
- Understanding of the relative balance between demand pull and supply push policies needed to accelerate technological innovation remains an important gap. Data on global private investment in research and development is a major gap along in addition to public R&D figures in middle income and low income countries.
- The valuation of co-benefits from emission reduction has been studied comprehensively in the United States (Muller et al., 2011), but much less is known about other countries. This is important because taking these co-benefits into account could significantly lower the cost of emission reduction, and perhaps offer negative costs, in several sectors.

15.14 Frequently Asked Questions

FAQ 15.1 What kind of evidence and analysis will help us design effective policies?

Economic theory can help with policy design at a conceptual level, while modelling can provide an ex-ante assessment of the potential impact of alternative mitigation policies. However, as theory and modelling tend to be based on sets of simple assumptions, it is desirable that they are complemented by ex-post policy evaluations whenever feasible. For example, theory and bottom up modelling suggest that some energy efficiency policies can deliver CO2 emission reductions at negative cost, but we need ex-post policy evaluation to establish whether they really do and whether the measures are as effective as predicted by ex-ante assessments (Section 15.4).

As climate policies are implemented, they can generate an empirical evidence base that allows policy evaluation to take place. If evaluation is built into the design of a program or policy from its inception, the degree of success and scope for improvement can be identified. Policies implemented at the sub-national levels provide sites for experimentation on climate policies. Lessons from these efforts can used to accelerate policy learning.

Much of the evidence base consists of case studies. While this method is useful to gain context-specific insights into the effectiveness of climate policies, statistical studies based on large sample sizes allow analysts to control for various factors and yield generalizable results. However, quantitative methods do not capture institutional, political and administrative factors and need to be complemented by qualitative studies.

FAQ 15.2 What is the best climate change mitigation policy?

A range of policy instruments is available to mitigate climate change including carbon taxes, emission trading, regulation, information measures, government provision of goods and services and voluntary agreements (Section 15.3). Appropriate criteria for assessing these instruments include: economic efficiency, cost effectiveness, distributional impact, and institutional, political and administrative feasibility (Section 15.5).

Policy design depends on policy practices, institutional capacity and other national circumstances. As a result, there is no single best policy instrument and no single portfolio of instruments that is best across many nations. The notion of best depends on which assessment criteria we employ when comparing policy instruments and the relative weights attached to individual criteria. The literature provides more evidence about some types of policies, and how well they score against the various criteria, than others. For example, the distributional impacts of a tax are relatively well known compared to the distributional impacts of regulation. Further research and policy evaluation is required to improve the evidence base in this respect (Section 15.12).

Different types of policy have been adopted in varying degrees in actual plans, strategies and legislation. While economic theory provides a strong basis for assessing economy-wide economic instruments, much mitigation action is being pursued at the sectoral level (Chapter 7-12). Sectoral policy packages often reflect co-benefits and wider political considerations. For example, fuel taxes are among a range of sectoral measures which can have a substantial effect on emissions even though they are often implemented for other objectives.

Interactions between different policies need to be considered. The absence of policy coordination can affect environmental and economic outcomes. When policies address distinct market failures such as the externalities associated with greenhouse gas emissions or the undersupply of innovation, the use of multiple policy instruments has considerable potential to reduce costs. In contrast, when multiple instruments such a carbon tax and a performance standard are employed to address the same objective, policies can become redundant and undermine overall cost effectiveness (Section 15.8.4.2).

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