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International Climate Change Policy

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Abstract

International cooperation to address the threat of climate change has become more institutionally diverse over the past decade, reflecting multiple scales of governance and the growing inclusion of climate change issues in other policy arenas. Cooperation under the United Nations Framework Convention on Climate Change has continued to evolve from the 1997 Kyoto Protocol to the 2015 Paris Agreement, while other governmental and private sector international fora for cooperation have arisen. As the level of activity in international cooperation on climate change mitigation has increased, so too has the related scholarly literature. In this review, we synthesize the literature on international climate change cooperation and identify key policy implications, as well as those findings most relevant for the research community. Our scope includes critical evaluation of the organization and implementation of agreements and instruments, retrospective analysis of cooperative efforts, and explanations of successes and failures.

1. INTRODUCTION

This review synthesizes the scholarly literature on international climate change cooperation, emphasizing the literature published over the last decade. Over this period, international cooperation under the United Nations (UN) has evolved considerably, culminating in the 2015 Paris Agreement. Simultaneously, climate change has become a focal issue in many other UN fora, non-UN multilateral and transnational fora, and nonstate international activities. While the institutional settings for climate policy have become more diverse, so too has the breadth of issues to which international climate policies have been linked.

We begin in Section 2 by identifying key framing concepts and criteria used to evaluate international climate change policies. In Section 3, we examine the major design elements of existing and proposed forms of international cooperation to address climate change. In Section 4, we describe existing fora and realizations of such cooperation, including the Kyoto Protocol and the Paris Agreement, and in Section 5, we provide an assessment of these forms and examples of international cooperation. In Section 6, we identify some additional issues, and in Section 7, we conclude.

2. FRAMING CONCEPTS AND EVALUATION CRITERIA

Greenhouse gases (GHGs) mix in the atmosphere, and so the benefits of GHG emissions reductions are distributed globally. These benefits are both nonexcludable—meaning an actor cannot be excluded from the benefits of emissions reductions undertaken by other actors—and nonrival—meaning the benefits of mitigation can be simultaneously enjoyed by any individuals without reducing the benefits to others. But the primary costs of climate policies are borne within the jurisdiction taking action. Hence, for virtually any jurisdiction taking action, the direct climate benefits it receives will be less than the direct abatement costs it incurs, creating incentives for countries to free ride on the mitigation actions of others (Stavins 2011). Because of this, international—if not global—cooperation is necessary to address climate change.

International cooperation can address several key challenges: multiple actors that are diverse in their perceptions of the costs and benefits of collective action, emissions sources that are unevenly distributed, heterogeneous climate impacts that are uncertain and distant in space and time, and heterogeneous mitigation costs. Because there is no world government, countries must consent voluntarily to any form of international cooperation, and compliance must be verified by parties to an agreement or by a legitimate body (Barrett 2003, 2007; Brousseau et al. 2012).

Following the Intergovernmental Panel on Climate Change (IPCC) (Stavins et al. 2014), we employ four categories of evaluation criteria for international climate policy: environmental effectiveness, aggregate economic performance, distributional impacts, and institutional feasibility. First, environmental effectiveness encompasses the extent to which a cooperative effort reduces the causes or impacts of climate change. This criterion has been formalized in various ways in several international agreements, including the stabilization of GHG concentrations at levels sufficient to "prevent dangerous anthropogenic interference with the climate system" (UN Framework Convention on Climate Change; UNFCCC); emission-reduction targets for developed countries (Kyoto Protocol); and an aspirational goal of limiting global average temperature increases to 2°C above preindustrial levels (Paris Agreement).

Second, aggregate economic performance incorporates both economic efficiency (maximization of social net benefits, including co-benefits and adverse side-effects) and cost-effectiveness (minimization of social costs for a given degree of environmental effectiveness) (Stern 2007, Nordhaus 2008). Although economic efficiency makes the trade-off between aggregate costs and benefits explicit, analysis of a policy's cost-effectiveness may be more feasible in the case of climate change, as some social benefits of climate change mitigation are highly uncertain and distant in

time, making them difficult to monetize or otherwise compare. Third, the distributional impacts of a cooperative effort refer to the distribution of costs and benefits across space and time. This criterion can be related to principles of distributive justice, historic responsibility, capability and capacity, and sustainable development (Stavins et al. 2014).

Fourth, institutional feasibility refers to the ability of the parties to an agreement to implement and sustain an effort. This criterion can be understood in terms of four components: participation, compliance, legitimacy, and flexibility. Participation refers to the number of parties, geographical coverage, and efforts of cooperating participants. Compliance affects long-term performance (Barrett 2003) but is often difficult to establish, due to the lack of supranational authority that can impose sanctions. However, incentives for compliance can be created within the regime established by an agreement (Heitzig et al. 2011). Legitimacy refers to whether parties believe that both the decision-making procedures and substantive outcomes fairly represent the collective will of the involved parties. Finally, flexibility refers to the degree to which a cooperative effort can respond to new information, learn from previous experience, and adapt to changing economic and political conditions.

These four criteria may be mutually reinforcing (Cao 2010), but there may also be conflicts, forcing trade-offs between and among them. Maximizing global net benefits or attaining cost-effectiveness may lead to actions that decrease distributional equity (van Asselt & Gupta 2009), which could lead to low participation. Increasing flexibility of an agreement may increase participation, but it can come at the cost of regulatory uncertainty that increases the aggregate cost of compliance by reducing incentives to invest in long-term solutions (Brunner et al. 2012). The environmental effectiveness of a cooperative effort largely depends on trade-offs between the ambition of the agreement, the breadth of participation, and effective compliance mechanisms (Barrett 2003, Bodansky 2011).

3. POLICY DESIGN ELEMENTS AND PROPOSALS FOR INTERNATIONAL CLIMATE POLICY

In this section, design elements of existing and proposed forms of international climate change cooperation are discussed: policy architecture, legal status, and mechanisms for monitoring and verifying mitigation actions.

3.1. Policy Architectures for Climate Change Mitigation and Adaptation

Policy architecture refers to the fundamental nature and structure of an international agreement or other climate regime (Aldy & Stavins 2010). We consider existing and potential policy architectures based on the level of centralized authority and the degree to which authority is conferred on a multilateral institution. Whereas international cooperation arises through negotiations between independent countries, agreed-upon policies vary in the degree to which they confer authority on centralized multilateral institutions. An alternative and closely related framing is of the degree of cooperation, which ranges from shallow coordination to deep cooperation.

3.2. Degrees of Centralized Authority

Policy architectures can be viewed along the spectrum of centralized authority within three categories: strong multilateralism, harmonized national policies, and decentralized approaches. The boundaries between these categories are not sharply defined, and the location of proposed and existing policies on the spectrum can depend on specific design elements.

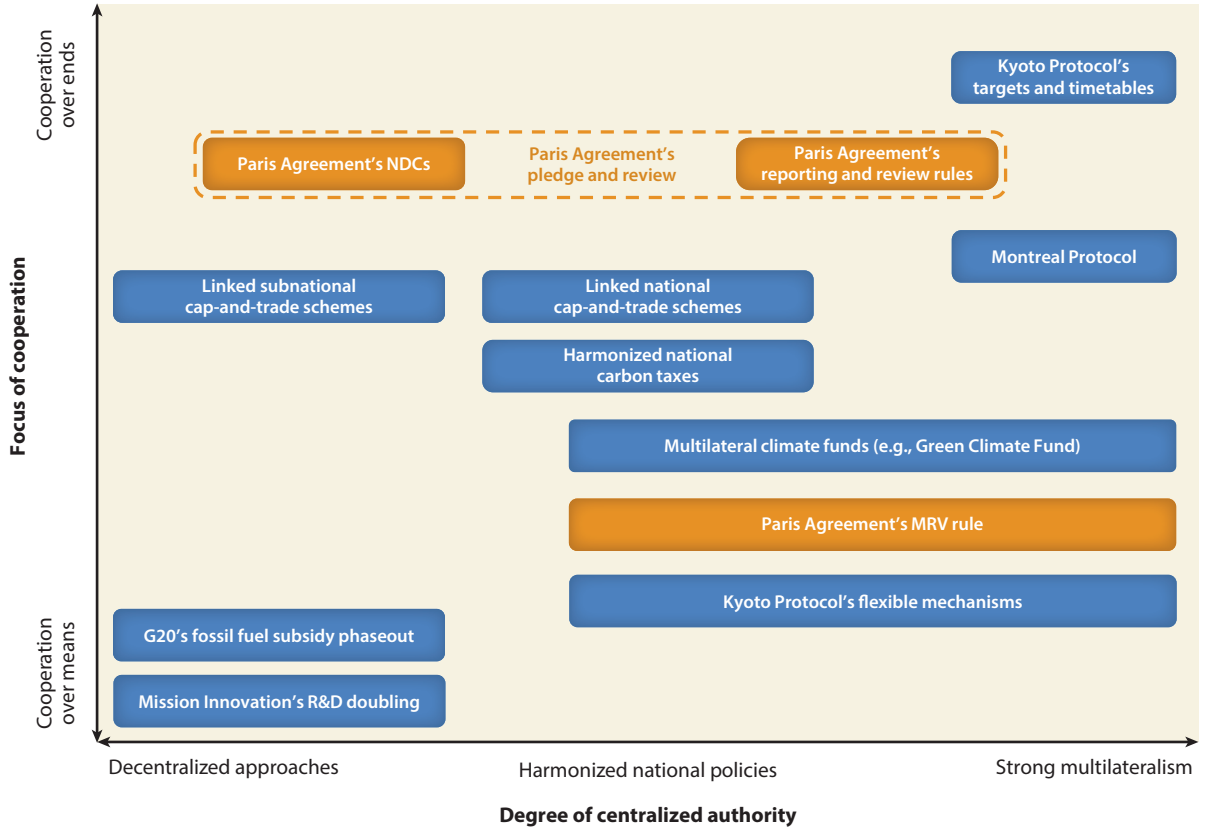

Figure 1

International cooperation over ends/means and degrees of centralized authority. Central elements of the Paris Agreement are highlighted in orange. The degree of centralization indicates the authority an agreement confers on an international institution, not the process of negotiating the agreement. Abbreviations: MRV, measurement (or monitoring), reporting, and verification; NDC, nationally determined contribution. Modified with permission from Stavins et al. (2014, figure 13.2).

Figure 1 illustrates how some existing and proposed international agreements can be placed on this spectrum of centralized authority. The figure also organizes policies by the degree to which their cooperative effort requires focus on ends, such as emission targets, or on means, such as policy instruments. Several policies shown in the figure span a range in their potential degree of centralized authority; more distinct placement would depend on specific design elements.

3.2.1. Strong multilateralism. Climate policy architectures based on strong multilateralism, also referred to as centralized or top-down approaches, are characterized by a high degree of coordination of goals or actions among participants (Bodansky 2007, Aldy & Stavins 2010). An example would be a global carbon tax or emission trading scheme administered by a single global organization. A prominent example of a centralized architecture is the Kyoto Protocol's emission targets and timetables for participating Annex B countries. Strong multilateralism may also be applied to individual sectors (Meckling & Chung 2009). While sectoral strong multilateralism may be more difficult to negotiate, these approaches may also have lower leakage rates if sectors can be regulated consistently across countries.

3.2.2. Harmonized national policies. Harmonized national policies involve cooperation to make the design and ambition of national (or other subglobal) policies similar to one another, relying less on centralized authority than on strong multilateralism. These approaches harmonize the rules of national policies—such as national carbon taxes (Nordhaus 2008, Metcalf & Weisbach 2009), emission trading schemes (Ellerman 2010), technology standards (de Coninck et al. 2008), or hybrid policy approaches (Metcalf & Weisbach 2012, Mehling et al. 2017)—at the international level. The "pledge and review" mechanism of the Paris Agreement exemplifies elements of the harmonized national policies approach in which participating parties to the agreement voluntarily commit to domestic emission targets or actions. Depending on how national pledges are reviewed (or enforced), a pledge and review approach could also include elements of centralized authority, particularly in the review of pledges, and therefore be considered a hybrid approach (Bodansky 2016b), which is the case with the Paris Agreement.

3.2.3. Decentralized approaches. Decentralized approaches, also referred to as bottom-up approaches (Victor et al. 2005, Dubash & Rajamani 2010), are national and other subglobal policies that are connected to varying degrees (Victor et al. 2005, Hoffmann 2011). These approaches may link climate policies relying on the same policy mechanism, such as cap-and-trade systems (Jaffe et al. 2009, Metcalf & Weisbach 2012, Ranson & Stavins 2013); may link climate policies relying on a heterogeneous set of mechanisms, such as a carbon tax and a cap-and-trade scheme (Metcalf & Weisbach 2012); or may focus on aspects of technology innovation and transfer (de Coninck et al. 2008, Newell 2010a). Decentralized approaches may therefore be seen as composed of topically focused building blocks (Falkner et al. 2010, Stewart et al. 2017) or as minilateral cooperation among clubs of countries (Nordhaus 2015). An example of a decentralized approach is the existing and proposed direct linkages between regional, national, and subnational cap-and-trade systems through the mutual recognition of allowances (Jaffe et al. 2009, Mehling & Haites 2009, Ranson & Stavins 2013, Mehling et al. 2017). A related but distinct example of a decentralized approach is the indirect linkage among cap-and-trade systems through mutual recognition of a common emission-reduction credit system, such as the Kyoto Protocol's Clean Development Mechanism (CDM) Certified Emission Reduction (CER) credits.

3.3. Legal Frameworks

International agreements exist only by the consent of their parties (Thompson 2006). Hence, the legal form of an agreement, together with its rules for enforcement, defines how legally binding the agreement is on its parties. The legal character of an international agreement can be understood in four parts: legal type, whether any commitments are mandatory, the specificity of commitments, and the use of enforcement provisions (Bodansky 2009).

Legal type refers to the range of forms under which an agreement is codified. At the opposite ends of a continuous spectrum are hard law and soft law. Examples of the former include treaties, protocols, and contracts, whereas examples of the latter include declarations, resolutions, and guidelines. The commitments contained in an agreement may be more or less legally binding: They can be expressed in obligatory language (for example, "shall" or "must") or in aspirational language (for example, "should" or "aim"). But the actual bindingness of an agreement may depend on the costs of nonparticipation, noncompliance, withdrawal, and loss of reputation (Hoffmann 2005, 2011). The specificity of an agreement refers to the degree of detail in which commitments are expressed. Compliance with a vaguely worded commitment is difficult to verify (Abbott & Snidal 2000). Finally, enforcement refers to an agreement's utilization of procedures, mechanisms, or sanctions, including monitoring and verification of compliance, which can range from inaction to admonishments to trade sanctions to military force (Werksman 2010).

3.3.1. Legal forms. Proposed and existing forms of international climate change cooperation can be grouped into five categories that describe their legal bindingness. First, an international agreement may be formalized as mandatory provisions in a legally binding instrument with obligatory language, requisite specificity to assess compliance, and a well-defined enforcement regime. The targets and timetables approach of the Kyoto Protocol and the Marrakech Accords are in this category, with specific emission limits and sanctions for noncompliance.

Second, an agreement can take the form of mandatory provisions in a legally binding instrument but without enforcement mechanisms, relying instead on self-enforcement. An example of such an agreement is Article 4.1 of the UNFCCC, which mandates national emission inventories, measures to mitigate, and measures to facilitate adaptation, but without any enforcement mechanisms.

Third, an agreement can consist of nonmandatory provisions in a legally binding instrument, carrying more weight than a political agreement but without demanding compliance. An example is Article 4.2(a) and (b) of the UNFCCC, in which developed countries commit to adopt policies and measures to limit their net GHG emissions.

Fourth, an agreement can take the form of mandatory provisions in a nonlegally binding instrument, which can induce actions through norms, reputation concerns, or reciprocity. An example of an agreement of this form is the pledges and actions submitted by states under the Copenhagen Accord, Cancún Agreements, and the Paris Agreement.

Fifth and finally, an agreement can be formalized as nonmandatory provisions in a nonlegally binding agreement. Such agreements typically include statements of principles or norms and are expressed as aims or aspirations. An example is the target set in the Noordwijk Declaration at a ministerial summit prior to the 1992 Rio summit.

An agreement's legal form can have important implications for the agreement's effectiveness. Agreements that are more legally binding increase the costs of noncompliance and therefore signal greater seriousness by participating states. But there may be trade-offs between a more legally binding agreement and the ambition of commitments, precisely because greater legal bindingness creates higher costs for failing to achieve commitments. Countries may be more willing to accept ambitious commitments in the context of a less legally binding agreement (Bernstein 2005, Raustiala 2005, Guzman & Meyer 2010).

3.3.2. Legal remedies and loss and damage. Although a scholarly literature exists on the potential use of legal remedies (such as civil liability) to address climate damages (Allen 2003, Grossman 2003, Lord et al. 2011), such remedies have not been incorporated in climate agreements, and there would be significant obstacles to doing so, including the lack of a robust international civil liability system. In this context, the notion of "loss and damage" has been discussed in UNFCCC negotiations, but the Paris Agreement removes the possibility of liability or obligatory compensation for climate impacts (Bodansky 2016a, Lees 2017). Human rights law could conceivably frame an approach to climate change (Bodansky 2010, Bell 2013), as has been acknowledged by the UN Human Rights Council in its Resolution 7/23 and the Office of the UN High Commissioner for Human Rights (Limon 2009), but this has not moved forward in UNFCCC negotiations.

3.4. Frameworks for Monitoring, Reporting, and Verification

Successful compliance is likely to require an effective regime of measurement (or monitoring), reporting, and verification (MRV). Provisions for greater transparency in MRV have been considered with regard to countries' GHG emissions and international financial flows from developed to developing countries for mitigation and adaptation (Breidenich & Bodansky 2009, Ellis & Moarif 2009). Lessons regarding effective MRV are available from other multilateral regimes—such as International Monetary Fund (IMF) consultations, Organisation for Economic Co-operation and

Development (OECD) economic policy reviews, World Trade Organization (WTO) trade policy reviews, and arms control agreements. Such lessons are in reference to attention to accuracy, evolution over time, self-reporting and third-party verification, independent technical assessment, political or peer review, remote sensing or other technical means, and public domain reporting (Cecys 2010, Bell et al. 2012, Aldy 2014).

4. EXISTING FORMS AND FORA OF COOPERATION

Over the past decade, the landscape of international institutions related to climate policy has become more diverse, as climate change is now addressed in a substantial number of fora across a wide range of scales. Some researchers have described the range of climate policy agreements and institutions as a "regime complex" (Biermann et al. 2009, Keohane & Victor 2011, Jordan et al. 2015). We review the evolution of international and transnational cooperation on climate change between state and nonstate actors over the past decade. State actors include governments at the international, national, and subnational levels, some of which may be parties to an agreement and others of which may be affected by an agreement to which they are not direct parties. Nonstate actors include nongovernmental organizations (NGOs) and private firms.

4.1. Internationally Negotiated Principles and Norms

International cooperation on climate change has been shaped by principles enunciated in several early norm-setting agreements, including the Rio Declaration on Environment and Development and the UNFCCC. The UNFCCC explicitly included principles designed to guide future international agreements: "equity" and "common but differentiated responsibilities and respective capabilities" (CBDR-RC) [Article 3(1)]; relative needs, vulnerability, and burdens in countries of differing wealth [Article 3(2)]; precaution and "cost-effective[ness] so as to ensure global benefits at the lowest possible cost" [Article 3(3)]; "sustainable development" [Article 3(4)]; and cooperation [Article 3(5)].

The UNFCCC established a framework, principles, and goals for the international response to climate change. Under Article 2, the parties agreed to the objective of "prevent[ing] dangerous anthropogenic interference with the climate system," an objective which was not quantified and was subject to caveats. Under Article 4(2)(a), the Annex I parties (largely the industrialized countries as of 1990) committed to adopt measures to limit net emissions (covering both sources and sinks of GHGs not controlled by the Montreal Protocol), "recognizing that the return by the end of the present decade (the year 2000) to earlier levels" would contribute to modifying long-term trends consistent with the treaty's objective. Under Article 4(2)(b), Annex I parties committed to periodically communicate information on their emissions, "with the aim of returning individually or jointly to their 1990 levels."

4.2. Cooperation Under the UNFCCC

The UNFCCC's universal membership provides it with a high degree of legitimacy among parties around the world (Karlsson-Vinkhuyzen & McGee 2013), and steps taken under the Convention have led to more extensive action than under other forms of international cooperation on climate change. Nevertheless, slow progress has been attributed to resistance to costly policies in both developed and developing countries, lack of political will (Keohane & Victor 2011), and the complexity that characterizes the problem (Hoffmann 2011). Fragmentation of the climate regime could create opportunities for forum shopping, loss of transparency, and reduced ambition (Biermann et al. 2009).

Although universal participation may be desirable in principle, nations are characterized by great heterogeneity in economic capacity and emissions levels. Variations in both wealth and emissions have evolved over time; for example, many countries classified in the 1992 UNFCCC as developing countries (non-Annex I) have since experienced increased incomes and emissions, in some cases exceeding the incomes and/or emissions of some countries classified in 1992 as developed (Annex I).

4.2.1. The Kyoto Protocol. The first Conference of the Parties (COP-1) of the UNFCCC met in Berlin, Germany, in 1995, and adopted what came to be known as the Berlin Mandate, which interpreted the UNFCCC principle of CBDR-RC as meaning that the Annex I countries alone should take actions to reduce their GHG emissions. This approach was quantified two years later at COP-3 in Kyoto, Japan, where the Kyoto Protocol was developed to include binding quantitative mitigation commitments for developed countries.

The 38 countries listed in the Kyoto Protocol's Annex B, nearly identical to the list of countries in the Convention's Annex I, made aggregate commitments to collectively reduce their GHG emissions by 4.2% relative to 1990 levels (5.2% relative to the country-specific base years used for establishing national commitments) by the end of the Protocol's first commitment period, 2008–2012 (UNFCCC 2012). Other parties to the Kyoto Protocol were not constrained but could participate in other ways, in particular, through the CDM.

Negotiations on a second commitment period for the Kyoto Protocol were launched in 2005 and concluded in late 2012 with the establishment of a second commitment period for 2013–2020. However, by that time, several major Annex I countries had decided not to participate in the first commitment period, decided not to participate in the second commitment period, or dropped out altogether (including the United States, Russia, Canada, Japan, and Australia). The remaining Annex I parties (largely the European Union and its member states) adopted quantified emissions reduction commitments covering approximately 13% of global GHG emissions (as of 2010) (JRC 2013).

The aggregate emissions by Annex I countries fell below the Kyoto Protocol's first commitment period collective 5.2% reduction target (Shishlov et al. 2016), but much of the reduction was due to factors other than the Protocol. According to UNFCCC GHG inventories, aggregate GHG emissions from all Annex I countries were reduced by 13.6% from 1990 to 2011 if land-use and forestry-sector changes are taken into account and 8.5% if they are not. Excluding the United States—because it was not a party to the Kyoto Protocol—the reduction from 1990 to 2011 was 22.9% if land-use and forestry-sector changes are taken into account and 16.6% if they are not. If the economies in transition (EITs)—largely the former countries of the Soviet Union—are excluded, the remaining Annex I countries' aggregate GHG emissions increased by 2.1% and 3.2% from 1990 to 2011 (with and without changes in land use and forestry, respectively) (UNFCCC 2012). Thus, the fall in aggregate emissions was largely due to the economic restructuring that ensued in the EITs.

The environmental effectiveness of the Protocol's first commitment period was less than it could have been for several reasons. First, only Annex B parties had emissions reduction responsibilities. Second, not all Annex B parties participated. The United States did not ratify the Protocol; Canada withdrew from the Protocol in December, 2011 (effective December, 2012); and Russia, Japan, and New Zealand opted not to participate in the second commitment period (2013–2020). Third, the Annex B EITs were credited for emissions reductions that would have occurred without the Protocol due to their significant economic contraction during the 1990s. But these loose targets may have been necessary to engage them as parties (Stewart & Wiener 2003).

Since 1990, the Annex B countries' share of global GHG emissions declined significantly, from approximately 56% of global emissions in 1990 to about 39% in 2010. Simultaneously, overall global GHG emissions have risen significantly; global emissions in 2010 were 31% higher than in 1990 (JRC 2013), with the bulk of this increase coming from the large rapidly growing and emerging economies (notably China, India, Brazil, South Korea, South Africa, Mexico, and Indonesia).

Assessments of the efficiency of the Kyoto Protocol depend on respective estimates of the costs and benefits of mitigation, and so some assessments have found the Protocol inefficient (Nordhaus 2007), whereas some have found it to be cost-effective but insufficient in its ambition (Stern 2007, Weitzman 2007). The Kyoto Protocol provides complete flexibility with regard to how parties achieve their targets. One result was the development of emissions trading programs in several countries and regions (Paterson et al. 2014). Regional and national emissions trading programs included those in the European Union (the EU Emission Trading System or EU ETS), Australia, and New Zealand, as well as subnational trading programs in the United States Regional Greenhouse Gas Initiative (RGGI) and in California. In China, seven regional pilot programs were launched in 2013, which were expected to expand to a national program in 2017 (Newell et al. 2013, Ellerman et al. 2016).

Distributional impacts of the Kyoto Protocol have been examined both cross-sectionally (mainly geographically) and temporally. Income patterns and trends as well as distribution of GHG emissions have changed significantly since the 1990s, when the UNFCCC and Kyoto Protocol specified Annex I/Annex B countries; some countries outside these lists have become wealthier and larger emitters than some countries on these lists (Aldy & Stavins 2012). However, among Annex B countries, the Kyoto Protocol's emissions-target allocation is generally progressive, exhibiting positive correlation between gross domestic product per capita and the degree of targeted emissions reduction below business-as-usual levels (Frankel 2005).

It is notable that the Kyoto Protocol was ratified (or the equivalent) by 191 countries (plus the European Union), but the high rate of ratification was likely due in part to the lack of emissions reduction commitments asked of non-Annex B countries (Lutter 2000). Also, allowing Annex B countries the flexibility to choose their own domestic policies to meet their national emissions commitments contributed to institutional feasibility. But compromises made during the negotiation of the Protocol that enabled its institutional and political viability may have reduced its environmental effectiveness (Victor 2004, Helm 2010). This serves as an example of a trade-off among ambition, participation, and compliance. Additionally, despite the Kyoto Protocol's compliance system, it was difficult in practice to enforce its targets because of the lack of a legal authority with enforcement powers, and the weakness of possible sanctions relative to the costs of compliance. This is, of course, true of most international agreements (Barrett 2008).

4.2.2. The Kyoto Protocol's flexible mechanisms. The Kyoto Protocol included three flexible mechanisms intended to reduce the aggregate costs of achieving the Protocol's emissions reduction targets by allowing for trading of emission permits between Annex B countries (international emissions trading or IET) and by expanding the scope of emissions reduction opportunities to additional reductions within Annex B countries (joint implementation or JI) and in non-Annex B countries (CDM). Activity under IET and JI was relatively limited.

The CDM aimed to reduce mitigation costs for Annex B countries and contributed to sustainable development in non-Annex B countries. Nearly 1.4 billion emission credits were issued from over 7,300 registered projects by October 2013 (Stavins et al. 2014). The price of CDM credits declined following the 2008 recession, due largely to decreased demand after rule changes in the EU ETS regarding the use of CDM credits. New project registration slowed significantly after late 2013 (UNEP Risoe Cent. 2017).

The environmental effectiveness of the CDM depended on three key factors: whether a credited project actually reduced more emissions than would have been reduced in its absence (additionality); the validity of the baseline from which emissions reductions were calculated; and indirect emissions impacts caused by projects (leakage). The issue of additionality, in particular, generated considerable controversy regarding environmental performance despite increased elaboration of additionality tests used by CDM regulators (Chan 2015, Chan & Huenteler 2015, Hayashi & Michaelowa 2013, Millard-Ball & Ortolano 2010).

With respect to cost-effectiveness, the Kyoto Protocol's three flexible mechanisms (the CDM, JI, and IET) were intended to lower the cost of the global regime. Although the CDM had the greatest volume of activity, many low-cost opportunities were not taken up by CDM projects (Castro 2012). However, the long-term contribution of the CDM to cost-effectiveness may have depended on its ability to promote technological change in developing countries (Dechezleprêtre et al. 2008, Seres et al. 2009). IET could, in theory, have reduced abatement costs by as much as 50% if trades took place among Annex B countries (Bosetti et al. 2010, Jacoby et al. 2010). But in practice, trading under this mechanism was very limited, with only 0.2 billion tCO_2eq traded through IET as of July 2013 (Stavins et al. 2014). JI also had the potential to improve the cost-effectiveness of Annex B countries' activities under the Protocol (Böhringer 2003), but activity was limited, with a majority of the 0.8 billion emission reduction unit (ERU) credits issued under JI coming in the transition economies.

4.2.3. Negotiations from Kyoto to Paris. Due to the recognition by some parties that the structure of the Kyoto Protocol, including its dichotomous distinction between developed and developing countries, was not consistent with achieving the GHG emissions reduction goals embodied in the UNFCCC, the annual climate negotiations increasingly considered alternative structures for a post-Kyoto period. With the planned conclusion of the First Commitment Period of the Kyoto Protocol in 2012, scholars and practitioners explored a variety of options for new climate policy architectures. Several reviews of alternative international policy architectures have appeared in the literature (Aldy & Stavins 2010, Moncel et al. 2011, Stavins et al. 2014).

At COP-13, in Bali, Indonesia, in 2007, the blurring of the Annex I/non-Annex I distinction commenced with discussions on long-term cooperative action under the UNFCCC, which led to the Bali Action Plan. Further, under the Copenhagen Accord of 2009 and the Cancún Agreements of 2010, 42 developed countries (including the 27 EU member states) submitted to the UNFCCC absolute emissions reduction commitments against various base years in the form of quantified economy-wide emissions targets for 2020, and 55 developing countries submitted information regarding Nationally Appropriate Mitigation Actions.

COP-17, held in Durban, South Africa, in 2011, produced an important breakthrough in the form of the Durban Platform for Enhanced Action, through which delegates agreed "to launch a process to develop a protocol, another legal instrument or an agreed outcome with legal force under the Convention applicable to all parties" for implementation in 2020. The 2013 Warsaw mechanism established a loose timeline for all parties, without differentiation between developed and developing countries, to offer Intended Nationally Determined Contributions (INDCs), which would represent each country's planned mitigation actions.

4.2.4. The Paris Agreement. At COP-21, held in Paris, France, in December, 2015, the delegates agreed to the Paris Agreement, which formalized the most comprehensive framework for international climate policy since the 1997 Kyoto Protocol. The central component of the Paris Agreement is a pledge and review system of nationally determined contributions (NDCs)

that represent roughly 10-year national goals for climate mitigation. In some cases, NDCs also contain pledges concerning adaptation, finance, and other measures (UNFCCC 2016).

The NDC submissions were compiled in April, 2016. Participation in this first round included NDCs covering nearly all parties to the UNFCCC and countries responsible for 97% of global GHG emissions (compared with 13% coverage by the Kyoto Protocol's second commitment period). The structure of the mitigation targets in the first round of NDCs varies significantly: 32% contain absolute emissions reduction targets; 45% contain emissions targets relative to business as usual; 4% include emission intensity targets (emissions per unit of GDP); 2% specify a year in which emissions will peak; and 20% include only strategies, plans, or actions for lowering emissions. In addition, some NDCs also include conditional mitigation pledges that peg domestic targets to the actions of other countries (UNFCCC 2016).

The legal form of the Paris Agreement is a mix of mandatory (e.g., procedural obligations to prepare and communicate successive NDCs every five years and comply with international transparency requirements) and nonmandatory provisions (e.g., the collective aim to peak global emissions as soon as possible) (Bodansky 2016a, Oberthür & Bodle 2016). The combination of top-down centralized elements with the bottom-up voluntary NDCs has led some to characterize the Paris Agreement as having a hybrid structure.

In terms of its eventual environmental performance, the first set of NDC pledges is surely not sufficient to meet the ambition of the Paris Agreement to limit global average temperature to "well below 2°C above preindustrial levels," let alone the Agreement's aspirational reference to 1.5°C (Rogelj et al. 2016, UNFCCC 2016, UNEP 2017). Relative to global emissions in 2010, the combined NDC pledges are estimated to result in global emissions that are 13% and 16% greater by 2025 and 2030, respectively. But, importantly, pre-NDC trajectories suggest that global emissions would have been considerably greater in the absence of the Paris Agreement (UNFCCC 2016).

Many NDCs endorse domestic and international market-based mechanisms, among various approaches, to improve cost-effectiveness. The Paris Agreement allows for countries to link their mitigation policies, thereby potentially improving aggregate cost-effectiveness (see Section 4.2.4.2) (Ranson & Stavins 2015, Bodansky et al. 2016, Mehling et al. 2017).

The distributional equity of the Paris Agreement could be increased through financing of emissions reductions and adaptation in developing countries. Studies have suggested potential approaches to providing financial resources (AGF 2010, Haites 2011).

The participation of 169 ratifying parties to the Paris Agreement speaks to the institutional feasibility of the Agreement, but the June 2017 announcement by the United States of its intention to withdraw from the Paris Agreement (effective November 2020) raised concerns about the durability of the Agreement and the future collective ambition of NDCs (Kemp 2017).

4.2.4.1. Increasing ambition under the Paris Agreement. The initial set of NDCs from countries accounting for 97% of global GHG emissions was intended only as the first of a series of NDCs with increasing ambition over time. The Paris Agreement establishes a time line for countries to submit revised NDCs every five years. Due to the voluntary nature of the contributions, the ambition of the overall Agreement is fundamentally rooted in national political realities and within an international system of accountability and periodic international review of domestic actions.

At the international level, the so-called "ratchet mechanism" of the Paris Agreement aims to increase the ambition of NDCs over time through five-year cycles of "stocktaking" to report, review, and revise pledges. The logic of the ratchet mechanism is to leverage soft reciprocity among states, whereby leading states take more ambitious actions with the aim of encouraging other states to reciprocate by raising their own levels of ambition. In the absence of coercive international law, the logic of the Paris Agreement's ratchet mechanism emphasizes political leadership, financial

transfers, moral suasion, and norm setting (Falkner 2016) and could create an expanded role for nonstate actors to influence international policy (van Asselt 2016).

A significant challenge to conducting the periodic review of NDCs will be developing a common understanding of the effort that country pledges represent. Because NDCs are articulated according to a variety of metrics, no single comprehensive metric can be universally applied. Instead, a set of indicators may be required to compare mitigation efforts (Aldy & Pizer 2016). Effectively comparing efforts may require additional analytic methods (Aldy et al. 2016, Jacoby et al. 2017, Peters et al. 2017) as well as additional transparency, surveillance, and accounting efforts (Aldy 2014, Winkler et al. 2017).

4.2.4.2. International linkage consistent with the Paris Agreement. Given concerns regarding the collective ambition of the NDCs submitted under the Paris Agreement, an important pending question is how to provide a structure and incentives that can facilitate increases in ambition over time. Some have argued that international linkage of regional, national, and perhaps subnational policies can be part of the answer by providing a means for parties to receive credit for actions they facilitate in other jurisdictions, thereby reducing aggregate compliance costs and hence facilitating greater ambition over time (Ranson & Stavins 2015, Bodansky et al. 2016, Mehling et al. 2017). It has been estimated that international linkage could reduce the cost of achieving the emissions reductions specified in the initial set of NDCs under the Paris Agreement by 32% by 2030 and by 54% by 2050 (World Bank Group 2016).

Linkage may take different forms. These range from hard linkage, which links systems through formal recognition of programs across jurisdictions to allow for flexibility in where emissions reductions take place (as in the case of the existing link between cap-and-trade systems in California and Quebec), to soft linkage, which can entail a variety of measures to harmonize carbon prices across jurisdictions (e.g., through a mutually agreed upon carbon price collar within a club) (Burtraw et al. 2013, Mehling et al. 2017).

The bottom-up nature of the Paris Agreement has led to great heterogeneity in the set of participating countries' policies in five categories: policy instrument, level of government engaged (regional, national, or subnational), status under the Paris Agreement (party or non-party), type of policy instrument target, and type of NDC target (Ger. Emiss. Trading Auth. 2016a). Heterogeneity per se need not be an impediment to linkage (Metcalf & Weisbach 2012), but there is a role for guidance on the key provision in the Paris Agreement for linking: Article 6.2 (Mehling et al. 2017). Article 6.2 is a reasonable vehicle to facilitate linkage because this article provides for international transferable mitigation outcomes (ITMOs), which can serve as an accounting mechanism to track international transfers to quantify mitigation targets and outcomes; avoid double-counting of emission reductions; and accommodate different metrics for, and vintages of, targets and outcomes (Ger. Emiss. Trading Auth. 2016b).

Among the accounting rules that could be specified in guidance on Article 6.2 are: standards and procedures for quantifying mitigation outcomes (whether through carbon taxes, cap-and-trade instruments, performance standards, or other policy instruments); registry tracking of the transfer and use of ITMOs; guidance on NDC elements that would increase clarity; and guidance to move NDCs to greater consistency, such as with regard to assumed global warming potential (GWP) values. Guidance could also establish whether and how transfers to or from non-parties (or subnational jurisdictions in parties or non-parties) can be accounted for.

If guidance extends much beyond basic accounting rules, restrictive requirements could impede effective linkage (Mehling et al. 2017). A combination of common accounting rules and absence of restrictive criteria and conditions could accelerate linkage and thereby increase the latitude of parties to scale up the ambition of their NDCs.

4.3. Other United Nations Institutions

Acting on climate change may require functions other than negotiation under the UNFCCC, as well as other forms of high-level cooperation, such as analytical support and implementation assistance for mitigation and adaptation efforts. A diverse set of fora both within and outside the UN system have focused to some degree on climate change over the past several decades (Depledge 2006).

The UN Environment Program (UNEP) has provided analytical support to the international process, in part through its emissions gap reports (UNEP 2017), but also through a wide range of other analytical efforts and support for institution building. UN fora beyond the UNFCCC address funding for adaptation and mitigation, but fragmentation of funds may make it difficult for developing countries to access funding (Czarnecki & Guilanpour 2009). Concerns exist regarding the additionality of official development assistance, that is, how much climate finance is actually new and additional (Smith et al. 2011).

4.3.1. The Montreal Protocol. The Montreal Protocol on Substances that Deplete the Stratospheric Ozone Layer (concluded in 1987 under UN auspices)—and the Protocol's subsequent amendments, adjustments, and decisions—have achieved nearly universal participation and have made significant contributions to reducing GHG emissions (Velders et al. 2007, Molina et al. 2009), as the UNFCCC does not address GHGs already controlled by the Montreal Protocol. In its effort to reduce emissions of ozone-depleting substances (ODSs), the Montreal Protocol initially phased down chlorofluorocarbons (CFCs), which harm the ozone layer and also have very high GWP. In 2007, it accelerated the phasedown schedule for hydrochlorofluorocarbons (HCFCs), an interim replacement for CFCs with a somewhat lower but still significant GWP. The latter decision was affected by climate considerations (Bodansky 2011). Even before the HCFC decision, the Montreal Protocol's overall net contribution to climate change mitigation may have been five times what the Kyoto Protocol achieved during its first commitment period (Velders et al. 2007, 2012).

Hydrofluorocarbons (HFCs) are being widely adopted as a longer-term substitute for CFCs and HCFCs. Many of these have extremely high GWP, and their use will partially negate climate gains otherwise achieved by the Montreal Protocol. The 2016 Kigali Amendment to the Montreal Protocol would accelerate the phaseout of HFCs, which are not ODSs but are strong GHGs (Velders et al. 2012, Hurwitz et al. 2016).

The Montreal Protocol applied equally stringent emission requirements on all countries but allowed for a 10-year grace period for countries with low per-capita CFC consumption to meet their requirements. The Montreal Protocol also established mechanisms for financing and provided technical support to assist developing countries in reducing their ODS emissions. The most notable mechanism is the Multilateral Fund, which has transferred more than US$3 billion to assist developing-country ODS mitigation (Molina et al. 2009). The experience of the Montreal Protocol illustrates how transfers can engage participation by major developing countries through financial and technological assistance (Andersen et al. 2007).

4.4. Non–United Nations International Fora for Climate Change Cooperation

Climate change is increasingly addressed in fora for international cooperation outside of the UN. Some international partnerships have defined themselves as complements to the UNFCCC, rather than as alternatives. For example, the REDD+ Partnership helps coordinate measures for reducing emissions from deforestation and degradation (REDD) in the UNFCCC process. In

2010, more than 50 countries signed a nonbinding agreement to pledge more than $4 billion to REDD+ (Bodansky & Diringer 2010). In addition, several energy-specific multilateral and plurilateral fora are linked to climate change, including the International Energy Agency (IEA) and the International Renewable Energy Agency (Florini 2011, Urpelainen & Graaf 2015).

The United States, during the administrations of Presidents George W. Bush and Barack Obama, organized the Major Economies Forum on Energy and Climate Change (MEF). The MEF provided a forum for informal discussion of policy options and international collaboration with regard to climate and energy. The MEF may have increased the fragmentation of global environmental governance (Biermann & Pattberg 2008, Biermann 2010). Activities under the MEF largely halted following the Paris Agreement.

The Group of Twenty (G20) finance ministers from the largest (industrialized and developing) economies could have the capacity to address climate finance, building on the G20's core mission to discuss economic and finance policy. At its meeting in Pittsburgh in 2009, the G20 agreed to "phase out and rationalize over the medium term inefficient fossil fuel subsidies while providing targeted support for the poorest." This effort would significantly affect GHG emissions if countries actually implemented it; by one modeled estimate, a complete phaseout of such subsidies by 2020 could reduce CO_2 emissions by 4.7% (IEA 2011). A remaining challenge is how pledges to reduce fossil fuel subsidies can be monitored and enforced (Aldy 2017).

Since 2005, the smaller Group of Eight (G8) heads of state and heads of government have held a series of meetings related to climate change and have affirmed a goal that global average temperature not exceed 2°C above preindustrial levels. At the 2007 G8 summit, member countries agreed (without any binding commitment) to set a goal of a 50% reduction in GHG emissions by 2050 (van de Graaf & Westphal 2011).

4.5. Nonstate Forms of International Cooperation

A prominent development over the past several decades has been the emergence of a considerable number of international agreements between and among nonstate entities, often referred to as transnational climate governance initiatives (Biermann & Pattberg 2008, Pattberg & Stripple 2008, Andonova et al. 2009, Bulkeley et al. 2012). In the most comprehensive survey, Bulkeley et al. documented 60 of these initiatives, which can be grouped into four principal types: public-private partnerships, private sector governance initiatives, NGO transnational initiatives, and subnational transnational initiatives.

The significance of partnerships between the private sector and government depends on their relationship with more traditional state-led governance. Partnerships may work once government regulations send strong signals to investors (Pfeifer & Sullivan 2008). Rules developed in private sector agreements may then become incorporated in government regulations (Knox-Hayes & Levy 2011). For example, private carbon market offset standards may be introduced into regulated carbon markets (Hoffmann 2011).

NGO transnational initiatives have attempted to influence the activities of businesses directly through transnational partnerships, some of which involve collaboration with the private sector. For example, certification schemes for carbon offset credits, such as the Gold Standard, have been established, as have forestry credit schemes, such as the Climate, Community and Biodiversity Alliance standard.

Subnational transnational initiatives have involved subnational actors, such as city-level governments, collaborating at an international scale. One example is the International Council for Local Environmental Initiatives (ICLEI)–Local Governments for Sustainability network, which has taken action through a multicity partnership, the C40 Cities Climate Leadership Group

(Román 2010, Bulkeley et al. 2012). Recognition of subnational and local governments as sources of capacity to meet the goals of the Paris Agreement is reflected in the Agreement's Article 11.

It remains unclear whether agreements among nonstate or subnational actors have been effective in reducing emissions. This is partly because the units of measurement to assess effectiveness are considerably more complex than for interstate agreements (Pinkse & Kolk 2009). For subnational efforts, the question of attribution requires better disaggregation to understand whether reductions are additional to national efforts or only contribute to delivering national pledges. While these subnational efforts may make a small contribution to climate action, they may be valuable in influencing nation states or helping them meet commitments (Osofsky 2012). That said, the smaller the geographic jurisdiction, the greater is the likelihood of emissions leakage, which can nullify the impacts of such efforts.

5. ADVANTAGES AND DISADVANTAGES OF DIFFERENT FORMS

There have been numerous studies of the strengths and weaknesses of negotiating climate policy across multiple fora and institutions. Some have suggested that, in addition to its own action, the UNFCCC effect of catalyzing efforts by others and providing coherence to multiple initiatives may result in greater aggregate impact (Moncel & van Asselt 2012). Others suggest that regime complexes may emerge from smaller clubs and then expand (Keohane & Victor 2011). Regimes need external incentives for participation and internal incentives for compliance (Aldy & Stavins 2010). An advantage of smaller fora (clubs) may be greater efficiency in the negotiation process, but disadvantages are that clubs lack universality and hence legitimacy (Moncel et al. 2011) and that the environmental effectiveness of clubs may be undercut by leakage outside the club (Babiker 2005). Some have suggested clubs as a way forward outside the UNFCCC, while others suggest they could contribute to the UNFCCC, catalyzing greater ambition (Sabel & Victor 2016).

The aggregate effectiveness of climate agreements and related institutions could be enhanced by coordination among multiple elements, but coordinating multiple agreements into a coherent whole is challenging in a fragmented world. Coordination may be stimulated by competition among public and private governance regimes (Helfer & Austin 2011), accountability (Ballesteros et al. 2010), learning (Kolstad & Ulph 2008), and experimentation (Sabel & Victor 2016).

In **Table 1**, we draw on the numerous studies referenced throughout this article to summarize assessments of the performance of existing international climate agreements, based on the four criteria introduced in Section 2. It is important to keep in mind that the performance of any individual policy depends on a wide array of interacting agreements and institutions at the international, national, and subnational levels of the landscape of climate change policy.

6. OTHER ISSUES

A number of cross-cutting issues arise when considering international cooperation to address climate change and related policies at the regional, national, and subnational levels. These include issue linkage, the role of investment and finance in international agreements, technological change and agreements targeting research and development activities, international governance of geoengineering, and the relationship between international cooperation and science policy.

6.1. Issue Linkage

Linkages across issues may help encourage participation. Such connections are separate and distinct from the policy instrument linkages considered in Section 4.2.4.2 in the context of the Paris

Table 1 Performance assessment of existing international fora of cooperation on climate change

Mode of international cooperation	Assessment criteria			
	Environmental effectiveness	Aggregate economic performance	Distributional impacts	Institutional feasibility
UNFCCC	Aggregate GHG emissions in Annex I (industrialized) countries declined by 6.0–9.2% below 1990 levels by 2000, a larger reduction than the apparent aim of returning to 1990 levels by 2000, but much of the decline is not attributable to the UNFCCC itself.	Authorized the joint fulfillment of commitments, multigas approach, sources and sinks, and domestic policy choice. Cost and benefit estimates depend on baseline, discount rate, participation, leakage, co-benefits, adverse effects, and other factors.	Commitments distinguish between Annex I and non-Annex I countries. Established a principle of common but differentiated responsibilities and commitment to equitable and appropriate contributions by each party.	Ratified (or equivalent) by 195 countries and regional organizations. Compliance depends on national communications.
The Kyoto Protocol	Aggregate emissions in Annex I countries were reduced by 8.5–13.6% below 1990 levels by 2011, more than the CP1 collective reduction target of 5.2%. Reductions occurred mainly in EITs and emissions increased in some other countries.	Cost-effectiveness improved by flexible mechanisms (JI, CDM, IET) and domestic policy choice. Cost and benefit estimates depend on baseline, discount rate, participation, leakage, co-benefits, adverse effects, and other factors.	Commitments distinguish between developed and developing countries, but dichotomous distinction correlates only partly (and decreasingly) with emissions trends and with changing economic circumstances.	Ratified (or equivalent) by 192 countries and regional organizations but took 7 years to enter into force. Compliance depends on national communications and compliance system. Approaches added to enhance measurement, reporting, and verification.
The Kyoto Flexible Mechanisms	Resulted in ~1.4 billion tCO_2eq credits under the CDM, 0.8 billion under JI, and 0.2 billion under IET (through October 2013). Additionality of CDM projects remains an issue.	CDM mobilized some, but not all, low-cost options. Evidence of underperformance of some project types. Some evidence that technology was transferred to non-Annex I countries.	Limited direct investment from Annex I countries. Domestic investment dominates, leading to concentration of CDM projects in several countries.	Helped enable political feasibility of Kyoto Protocol. Yielded largest carbon market to date. Has built institutional capacity in developing countries.

(*Continued*)

Table 1 (*Continued*)

Mode of international cooperation	Assessment criteria			
	Environmental effectiveness	**Aggregate economic performance**	**Distributional impacts**	**Institutional feasibility**
The Paris Agreement	Pledges were made to limit emissions by all emitters, covering 97% of global emissions. Goal was set to limit temperature change to 2°C with efforts to reach 1.5°C. Initial NDCs were insufficient for pathway to ultimate goals.	Cost-effectiveness might be improved by market-based policy instruments, policy linkage, and inclusion of a wide set of sectors.	Depends on sources and flows of financing, particularly for actions of developing countries. Preserves national authority.	Resulted in nearly universal participation in NDC framework but more limited participation in finance and technology support mechanisms.
G8, G20, MEF	G8 and MEF have recommended emission reduction by all major emitters. G20 may spur GHG reductions through phaseout of fossil fuel subsidies.	Action by all major emitters may reduce leakage and improve cost-effectiveness if implemented using flexible mechanisms. Potential efficiency gains may occur through subsidy removal.	Has not mobilized climate finance. Removing fuel subsidies would be progressive, but they have negative effects on oil-exporting countries and those with very low incomes, unless other assistance provided.	Led to lower participation of countries compared to UNFCCC but covers 70% of global emissions. Opens the possibility for forum-shopping based on issue preferences.
Montreal Protocol on ODS	Spurred emissions reductions through ODS phaseouts ~5 times the magnitude of Kyoto CP1 targets. Contribution may be negated by high-GWP substitutes, although efforts to phase out HFCs are included in subsequent amendments.	Cost-effectiveness supported by multigas approach. Some countries used market-based mechanisms to implement domestically.	Led to later compliance period for phaseouts by developing countries. Multilateral Fund provided US$3 billion in finance to developing countries.	Led to universal participation, but the timing of required actions varies for developed and developing countries.

Abbreviations: CDM, clean development mechanism; CP1, first commitment period of Kyoto Protocol; EIT, economy in transition; G8, Group of Eight; G20, Group of Twenty; GHG, greenhouse gas; GWP, global warming potential; HFC, hydrofluorocarbon; IET, international emissions trading; JI, joint implementation; MEF, Major Economies Forum on Energy and Climate Change; NDC, nationally determined contribution; ODS, ozone-depleting substance; UNFCCC, United Nations Framework Convention on Climate Change. Modified with permission from Stavins et al. (2014, table 13.3).

Agreement. Although some actors may participate in cooperative agreements to a greater degree than self-interest alone would predict, some emissions reductions may be provided without cooperation due to the linkage of climate change with other issues. Participation is likely to increase when otherwise self-beneficial actions on other issues create positive externalities, or co-benefits. For example, actions to reduce energy expenditures, enhance the security of energy supply, and reduce local air pollution can also reduce GHG emissions. However, policies designed to address climate change mitigation may also have negative externalities, reducing incentives for participation. For example, without compensating measures, climate policies may have a disproportionate impact on low-income populations (Hassett et al. 2009).

6.2. Investment and Finance in International Agreements

The UNFCCC and subsequent international agreements have created new institutions focused on finance for climate change mitigation and adaptation. Under the 2009 Copenhagen Accord, developed countries made a nonbinding pledge to mobilize $100 billion per year for climate finance, which may include public and private flows, may be inclusive of bilateral and multilateral funds (multilateral development banks and multilateral climate funds), and may also include grants and loans. A difficulty is that there is no agreement on climate finance definitions and accounting (Stavins et al. 2014). Recently, South-South climate funds have also been established (Hannam et al. 2015).

Several multilateral funds operate under or in coordination with the UNFCCC, including the Adaptation Fund, the Global Environment Facility (GEF), and the Green Climate Fund (GCF). These multilateral climate funds vary in their governance structures. For example, the Adaptation Fund is governed by a majority of developing countries, whereas the GCF is accountable to the Conference of the Parties to the UNFCCC. Contributions to climate funds are voluntary but primarily come from countries classified as Annex I under the Kyoto Protocol. As of early 2018, countries pledged just over $10 billion to the GCF, of which under 60% has been received. By country, the United States pledged $3 billion, and Japan, the United Kingdom, France, and Germany each pledged over $1 billion (GCF 2018).

6.3. Technological Change, R&D Agreements, and International Cooperation

The Technology Mechanism of the UNFCCC, with its subsidiary Climate Technology Centre and Network (CTCN) and Technology Executive Committee (TEC), was established in 2010 to exchange information and implement projects for climate change technology development and transfer. In theory, technology-focused climate agreements can improve the dynamic economic performance of climate mitigation by lowering mitigation costs and increasing environmental effectiveness (Barrett 2003), but such policies have limited environmental effectiveness in isolation (de Coninck et al. 2008, Newell 2010b).

International cooperation in clean energy R&D can take several different forms (de Coninck et al. 2008, Newell 2010a). These range from loosely coordinated pledges for domestic actions, such as the Mission Innovation pledges made during COP-21 to double clean energy R&D in the largest economies; plurilateral technology collaboration platforms, such as the IEA's Technology Collaboration Programmes and the CTCN; and minilateral integrated cooperative R&D centers with pooled resources and shared outputs, such as the US-China Clean Energy Research Center or the ITER fusion demonstration project. International cooperation can increase the efficiency of R&D investments by expanding the base of knowledge for new innovation, creating opportunities for cost sharing to enable R&D projects that are of greater scale and that are less duplicative of

domestic efforts, and taking advantage of specialization in specific technology areas or in certain R&D system functions within each geographic region (Malerba & Montobbio 2003).

In addition to providing opportunities for more efficient R&D investments, international cooperation can, in principle, accelerate the pace at which new energy technologies are deployed, particularly in developing countries (Lema & Lema 2012, Mallett 2013). The strength of national intellectual property rights regimes may have significant impacts on the effectiveness of such agreements, particularly those focused on technology transfer (Branstetter et al. 2006, Hall & Helmers 2010).

6.4. International Governance of Geoengineering

Geoengineering refers to approaches to lessen the impacts of climate change that are distinct from emissions mitigation and adaptation. Geoengineering takes two general forms: carbon dioxide removal and solar radiation management. Examination of the economics of these technologies is at an early stage (Heutel et al. 2016). The governance of geoengineering activities remains a challenge for the international regime, partly because there appear to be incentives for unilateral action, which may have negative consequences for other jurisdictions (Bodansky 2013, Barrett 2014, Parson 2014).

6.5. International Cooperation and Science Policy

Following the 2015 Paris Agreement, there have been calls to improve the use of scientific inputs in the international climate negotiation process (Kennel et al. 2016). Particular attention has been given to potential reforms of the IPCC to improve its procedures (Chan et al. 2016, Minx et al. 2017) and adjust to the changing demands of the policy process (Beck & Mahony 2017).

7. CONCLUSION

The 2015 Paris Agreement is only the most recent development in a multidecade history of international cooperation to address climate change, but it represents a significant milestone in the evolution of international cooperation in this realm. As laid out in this review, social science research has helped identify the impacts of past efforts at international cooperation, the trade-offs associated with different institutional design options, and future opportunities. As implementation of the Paris Agreement proceeds in parallel with other activities in an increasingly diverse landscape of loosely coordinated institutions, ongoing research that can inform decision making will become more important. Several key lessons have already arisen in the literature.

First, climate policy has emerged from a complex constellation of institutions and decision-making bodies, a so-called regime complex. The Paris Agreement is notable for its near universal participation, but past international environmental agreements suggest possible trade-offs between level of participation and degree of ambition. While the initial level of ambition in the Paris Agreement's set of NDCs may reflect this relationship, the Paris Agreement has adopted a structure distinct from past agreements in its reliance on authority at regional, national, and subnational levels of governance. Moving forward, as NDCs evolve, ambition can be increased by new climate mitigation and adaptation policies taken by a diffuse set of actors at different scales.

Second, to be environmentally effective, cost-effective, equitable, and institutionally feasible, international cooperative efforts need to take into account the complexity of the regime complex. New cooperative efforts demonstrate an evolution in the shifting authority given to actors at different levels of governance to account for this more complex structure. An example is the set of

efforts to pursue bottom-up linkage of national and subnational climate policies consistent with the structure of the multilateral Paris Agreement.

Finally, as climate change has become more salient in international dialogue, it has become linked with other international issues. While these other issues have become more prominent in shaping climate policy, climate has become more salient in the formation of policies in other areas. For example, the World Bank and other multilateral development banks have pursued efforts to "mainstream" climate change in all economic development initiatives. Simultaneously, a broader set of sustainable development issues, such as biodiversity preservation, ocean ecosystem management, human rights, and gender equality, are increasingly considered in the formulation of climate policy. As international policy continues to evolve, these linkages are likely to become deeper, and more opportunities for synergistic progress in multiple domains may emerge.

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