Closing the Emission Price Gap

Revised version

December 2014

Abstract

Even without internationally concerted action on climate change mitigation, there are important incentives for countries to put a price on their domestic emissions, including public finance considerations, internalizing the climate impacts of their own emissions, and co-benefits, such as clean air or energy security. Whereas these arguments have been mostly discussed in separate strands of literature, this paper carries out a synthesis that exemplifies how policies to put a price on emissions can be conceptualized in a multi-objective framework. Despite considerable uncertainty, empirical evidence suggests that different countries may face quite different incentives for emission pricing. For instance, avoided climate damages and co-benefits of reduced air pollution appear to be the main motivation for emission pricing in China, while for the US generating public revenue dominates and for the EU all three motivations are of intermediate importance. We finally argue that such unilateral incentives could form the basis for incremental progress in international climate negotiations towards a realistic climate treaty based on national interest and differentiated emission pricing and describe how such an agreement could be put into practice.

Keywords: Unilateral incentives, co-benefits, hybrid climate agreement

I. Introduction and Motivation

The Fifth Assessment Report of the Intergovernmental Panel on Climate Change reaffirms the serious consequences of unabated climate change (IPCC 2013). In order to avoid the adverse effects of 'dangerous anthropogenic interference with the climate system' (UNFCCC 1992) and to close the 'emission gap' between emission reductions from unilateral pledges under the Copenhagen Accord (UNFCCC 2009) and a trajectory that limits the risk of global mean temperature increase of more than 2°C, a list of actions specifying low-cost mitigation options in different sectors has been proposed (UNEP 2014). These include e.g. encouraging no-tillage practices and improved nutrient and water management in agriculture, appliance standards, building codes, or vehicle performance standards.

However, from an economic perspective, the perhaps most important prerequisite for cost-efficient climate change mitigation lies in imposing a globally uniform price on GHG emissions that approximates their social costs (Stern 2008; IPCC 2014) instead of determining abatement requirements for each economic sector and technology option. By means of a price on emissions the global externality associated with climate impacts would be internalized into the decisions of all individuals and organizations and market prices will ideally guide individual incentives towards socially optimal abatement efforts (but additional policies will be required to provide low-carbon public goods and target additional market failures). Yet, collective action theory has provided a pessimistic outlook regarding the feasibility of an optimal global emission price. It is argued that free-rider incentives would undermine incentives to participate in an international arrangement for the provision of the global public good of emission reductions (Barrett 1994; Carraro and Siniscalco 1993). Nevertheless, despite the lack of an internationally binding climate agreement, several countries (including 18 of the world's 20 largest emitters) have implemented policies that explicitly aim to reduce their GHG emissions (Dubash et al. 2013,(Townshend et al. 2013; IPCC 2014, Chapter 15).

This paper argues that even in the absence of a global climate agreement there are various unilateral, and in part short-term incentives for policy-makers to introduce mitigation measures, and in particular emission pricing. We exemplarily discuss incentives for unilateral climate policies, including (a) carbon pricing as an efficient source of public finance enhancing (at least in the short-term) economic growth, (b) opportunities to invest the revenues from carbon pricing in productive domestic uses (e.g. in public infrastructure), and (c) Pigouvian GHG pricing to value the domestic climate impacts of a country's own emissions as well as co-benefits. Whereas these arguments have been mostly discussed in separate strands of literature, this paper carries out a synthesis that exemplifies how policies which put a price on emissions can be conceptualized in a multi-objective framework, illustrated in Figure 1 and discussed in detail below. Even though the domestic incentives will likely be insufficient to achieve the globally optimal price for GHG emissions, each of them could contribute towards closing the 'emission price gap' between current GHG prices and a level that is globally desirable. Addressing several of these incentives simultaneously would be unlikely to result in an emission price equal to the sum of each incentive being addressed in isolation.

[Figure 1]

Early action by some countries, regions or industries could facilitate international negotiations to close (at least some part of) the current GHG price gap (Keohane and Victor 2011; Ostrom 2010; Urpelainen 2013). This paper discusses how unilateral emissions pricing could promote cooperation on the international level. Even though the literature in this respect is not very comprehensive, it has been shown that unilateral efforts can not only increase the overall level of climate change mitigation, but also promote collective action. Possible channels through which cooperation can be enhanced are via (a) technology spill-overs, (b) social learning with regards to uncertain costs and benefits as well as asymmetric information, (c) reciprocity and (d) changing the political economy and institution building. We propose that international negotiations should embrace approaches that provide flexibility to incorporate country-specific considerations, e.g. by means of a climate regime focusing on coordinating domestic policy packages instead of specific emission reduction quantities.

Top-down metrics such as a global temperature stabilization goal could be applied to evaluate the expected global aggregate outcomes of such packages to inform international negotiations with respect to the needs for enhancing the levels of climate policy ambition.

Recent years have witnessed the development of a vast literature related to proposals how to investigate international cooperation on climate change mitigation (Aldy and Stavins 2007; IPCC 2014) from a 'top-down' as well as a 'bottom-up' perspective (Aldy, Barrett, and Stavins 2003). This is echoed in Chapter 13 of the recent Fifth Assessment Report of IPCC Working Group III on international cooperation (IPCC 2014), which observes that "existing and proposed international climate agreements vary in the degree to which their authority is centralized", ranging from strong multilateral agreements to harmonized national policies and decentralized but coordinated national policies.

Top-down climate agreements start with a global temperature or concentration target. To define how this target should be achieved, it is broken down into actions by individual countries. A prominent example is the 'targets-and-timetables' approach under the Kyoto Protocol, which spells out binding national commitments to limit GHG emissions to a specific quantity for the period 2008-2012. Bosetti and Frankel (2011) and den Elzen and Höhne (2010) are examples for analyses of alternative options for specifying a future targets-and-timetables regime. In a similar vein, the so-called 'budget approach'(WBGU 2009), which aims at limiting cumulative global emissions for a certain time period (e.g. until 2050), is another top-down proposal for allocating emission quantities across countries. In contrast to quantitative limits, several authors have suggested to alternatively crafting a top-down regime by negotiating a globally harmonized carbon price (Nordhaus 2007; Cooper 2007; Weitzman 2013).

However, top-down approaches to regime design have frequently been criticized as being overly optimistic in their assumptions about the viability of international cooperation and hence unrealistic, as no country has sufficient incentives to provide the amount of the global public good of emission reductions that would be optimal from a social planner's perspective (Carraro and Siniscalco 1993; Barrett 1994; Barrett 2006). For this reason, bottom-up approaches start from policies that can be put into place from the perspective of national interest and then pose the question of how such individual national policies and measures can be combined to result in an international agreement. Prominent examples of such a bottom-up structure are technology cooperations aiming to harmonize standards and engage in joint R&D (de Coninck et al. 2008; Barrett 2006; Pizer 2007), or the linking of emission trading systems (Flachsland, Marschinski, and Edenhofer 2009) .

Our paper is not the first to discuss how national carbon pricing schemes introduced from a bottom-up perspective could lay the foundation for a global climate agreement. Victor (2011) emphasizes that domestic measures that are coordinated on the international level have the highest chance to result in a self-enforcing climate agreement over time and discusses how reciprocity and coordination might promote collective action. In a similar vein, Morris, McKibbin and Wilcoxen (2013) propose international 'Carbon Pricing Consultations' in order to coordinate pricing policies and share experiences regarding implementation issues.

However, these bottom-up proposals do not specify why countries should have an incentive to implement a carbon price that would result in an ambitious level of atmospheric stabilization in the first place. By combining the work on unilateral incentives for carbon pricing with the one on bottom-up climate agreements, our paper's contribution to the literature is twofold. First, by providing an overview of potential incentives for domestic carbon pricing policies, we exemplify how self-enforcing bottom-up carbon pricing schemes could be a first step towards achieving ambitious climate targets even if countries only act in their national self-interest. Second, we apply arguments in favor of a step-wise approach to introduce (unilateral) climate measures to the case of carbon pricing to demonstrate how unilaterally implemented pricing schemes might be strengthened and extended over time by means of international coordination. By emphasizing domestic incentives, our paper is similar to Stewart, Oppenheimer and Rudyk (2013), who propose to put actions that are not primarily aimed at climate change mitigation, but nevertheless reduce emissions (such as clean air policies) as a complement to strengthen the current UNFCCC system. By contrast, our approach explains how a global climate regime could arise from bottom-up incentives for domestic carbon pricing. Hence, this paper fills an important gap in the literature by combining the discussion of unilateral incentives for emission pricing in recent studies (Parry, Veung, and Heine 2014) with top-down climate regime designs focusing on price-based policies.

II. Incentives for Unilateral Carbon Pricing

II.1. Carbon Pricing as an Efficient Source of Public Finance

In order to finance the provision of public goods – such as healthcare, education, or transport infrastructure – governments need to levy taxes. With the exception of Pigouvian taxes introduced to correct a negative externality (see below), mainstream economic theory suggests that taxes usually induce a distortion in the economy by inhibiting desirable activities, such as investment or participation in the labor market (IFS and Mirrlees 2011). From this theoretical perspective, public goods should be provided to the extent that their marginal social benefit equals the marginal social costs induced by raising the required taxes. The theory of optimal taxation analyzes how to design tax systems in the least distortionary way (Mankiw, Weinzierl, and Yagan 2009). One central result of this kind of analysis is the Ramsey rule, stating that in order to raise a given amount of tax revenue economic factors should be taxed in inverse proportion to their demand elasticity (Ramsey 1927). That is, as economic distortions from taxation are smaller for goods for which demand is less responsive to changes in prices (i.e. which are more inelastic), the latter should be taxed at a higher rate. From this perspective, it would be economically rational to impose a price on GHG emissions merely for the sake of generating revenues, i.e. even if there were no related negative externalities (an alternative way to put a price on emissions consists in a tradable permit system with auctioned permits; we will treat these options as identical in outcome for the remainder of this paper, see e.g.

(Goulder and Parry 2008) for a review of the discussion of price and quantity instruments for climate policy).

The efficiency impacts of pricing negative externalities such as GHG emissions has been examined in the ‘double dividend’ literature (Goulder 1995; Parry 1995). This literature argues that pricing externalities can be beneficial on two accounts: first, by internalizing the externality, private marginal benefits of an activity are equalized to their social benefits, such that the resulting market outcome will be economically efficient. Second, the associated tax revenues can be employed to lower existing distortionary taxes (e.g. on income), which will produce an additional benefit. Even though this beneficial effect is – at least partially – offset by interaction with other pre-existing economic distortions (e.g. with a minimum wage, increased energy prices result in lower labor demand and hence more unemployment), it is more efficient to include the associated revenues in the government budget compared to e.g. lump-sum redistribution of revenues (as under the ‘cap-and-dividend’ approach), or free allocation of emission permits (as under the grandfathering approach). The latter would not lead to the macro-economic efficiency enhancements resulting from lowering pre-existing taxes (Goulder 2013). Recent studies have further shown that, by broadening the tax base, a price on GHG emissions increases the overall efficiency of the tax system in economies with a large informal sector, which is affected by a GHG price but would otherwise not be subject to taxation (Markandya, González-Eguino, and Escapa 2013). The above effects could thus, at least in the short term, foster economic growth by means of more efficient use of economic resources.

The double-dividend literature focuses on tax cuts to lower the costs of public funds. But numerous other macroeconomic and fiscal effects of climate policy both on the revenue-raising and spending side exist (see Siegmeier et al. 2014 for a detailed overview). Two examples for effects that also lower the costs of public funds concern capital mobility and investment behavior (the revenue spending side is treated in the next section).

Existing studies on the double dividend mostly ignore international capital mobility. In the presence of tax competition – i.e. to attract mobile capital – taxation of fossil fuel use can be more efficient than taxes on capital if the revenues are invested in productivity-enhancing infrastructure projects. International tax competition and resulting bottom-spiraling on capital taxation could thus be compensated for. The investments from revenues in turn could attract international capital and have therefore further potential to alleviate carbon leakage (Franks, Lessmann, and Edenhofer 2014).

Furthermore, a mechanism through which emission pricing could improve macro-economic performance that has only received little attention in the literature concerns the composition of investors' portfolios in the presence of fixed factors of production. Investment in productive assets such as land, but also in fossil resource stocks does not increase their supply. At the same time, investment in *producible* capital as the alternative asset may be sub-optimally low relative to what would be mandated from an inter-generational perspective that takes into account the welfare of future generations. This misallocation of economic resources can be – at least partially – corrected by taxing rents of the fixed factors used in production – such as fossil fuels –, which directs investment towards producible capital (Edenhofer, Mattauch, and Siegmeier 2013; Feldstein 1977; Siegmeier, Mattauch, and Edenhofer 2014).

II.2. Spending Revenues from Carbon Pricing

Due to its potential to raise revenues at low (or potentially even without) macro-economic distortions, carbon pricing constitutes an attractive source of public finance. This not only increases macro-economic efficiency by lowering the costs to raise the current amount of revenues as discussed in the previous section. Rather, lower marginal costs of public funds will result in a new equilibrium with higher revenues and higher public spending. Hence, revenues from emission pricing could for example be used for productive uses such as public debt reduction, or to increase public investment.

If the reduction of public debt is an objective of government policy, revenues from carbon pricing may be used for this purpose (Carbone et al. 2013; Rausch 2013). For this reason, carbon pricing has been recommended by some as an appropriate measure to balance government budgets suffering from the impacts of the current financial crisis (Vivid Economics 2012).

Alternatively, the provision of public goods or infrastructure investments, such as health, education, transport, or telecommunication, could be increased (Jakob and Edenhofer 2014). Higher levels of public infrastructure have been shown to be related to economic growth, reduced inequality (Calderon and Serven 2014) and improvements in human well-being (Drèze and Sen 2013). And it has been shown that in many cases the stock of public infrastructure is below its optimal level (Estache and Fay 2007). This argument is in accordance with investment needs related to public infrastructure to achieve human development goals, such as the currently discussed ‘Sustainable Development Goals’ (Griggs et al. 2013). For instance, in order to achieve universal energy access by 2030, Riahi et al. (2012) estimate that additional investments of US$ 36-41 bln per year in the global energy system, compared to the business-as-usual projection, are required. Likewise, Jamison et al. (2013) suggest that a ‘great convergence’ of global health standards can be achieved by investing about US$ 40 bln per year until 2035.

A tax on fixed factor rents (such as from fossil fuels) can directly finance otherwise underinvested capital stocks (Mattauch et al. 2013). This ensures that the social return to all factors of production (e.g. natural, physical, and human capital) is equalized. Thus, GHG pricing could help to cover these investments without introducing new (or increasing already existing) distortionary taxes. To give an impression of the amount of revenues from a carbon price that theoretically could be available, Figure 2 shows the range of tax revenues in different regions for scenarios assuming carbon prices of US$10, 30, and 50/ton of CO_2, as calculated with the integrated assessment model ReMIND-R. Depending on the magnitude of the global emission tax, total global revenues (in 2005 US$) range from USD 400 bln (in 2020 for a tax rate of USD 10) to USD 2100 bln (in 2030 for a tax rate of USD 50). For scenarios in which global actions is delayed or particular mitigation technologies are unavailable and thus higher GHG prices are required to achieve ambitious climate objectives, annual revenues may be higher (see Krey 2014 for a detailed discussion).

[Figure 2]

Revenues from GHG pricing could of course also be invested in public infrastructure that is directly related to climate change. Recent estimates suggest that an ambitious global mitigation target would require global investments in the power sector for transmission, distribution, and storage of between USD 267 - 597 bln per year (McCollum et al. forthcoming). As pointed out by Bowen et al. (2013), and in line with the order of magnitude of revenues shown in Figure 2, revenues from carbon pricing would provide more than sufficient funds to fully cover these investments. Even though a large share of investments for climate change mitigation will likely come from the private sector incentivized e.g. by a GHG price signal, public finance will arguably have a role to play. In the power sector, the largest utilities in industrialized countries as well as in India and China are often publicly owned, with at least partial public ownership in almost all cases, thus raising the issue of publicly financed decarbonization in case of these climate-relevant state owned enterprises (Koske et al. forthcoming). In the transport sector, cost-effective mitigation requires that private decisions are complemented by coordinated infrastructure investments. For example, to induce a shift towards cleaner modes of transport in cities, investments in public transport infrastructure or bicycle lanes are required (Bongardt et al. 2013).

Further investment needs arise for adaptation to the unavoidable impacts of climate change (Malik and Smith 2012), with costs to adapt to the likely impacts of climate change believed to amount to between US$ 25 bln per year to well over US$100 bln per year by 2015-2030 (Fankhauser 2010). Finally, addressing technology R&D market failures which are not appropriately tackled by a price on GHG emissions (Jaffe, Newell, and Stavins 2005; Kalkuhl, Edenhofer, and Lessmann 2012) would also require additional public support. However, these should be expected to be rather modest compared to energy system investments. According to the IEA (2014), in 2012 global spending on energy R&D

from public as well as private sources amounted to about US$ 18.5 bln (out of which roughly US$ 2.5 bln were dedicated to fossil technologies, US$4 bln to renewables, US$3 bln to energy efficiency and a bit less than US$5 bln to nuclear). An efficient up-scaling of these funds would require incremental increases to enable R&D systems to absorb them in a productive manner.

II.3. Internalizing Domestic Climate Change Impacts and Co-Benefits of Emission Reductions

The failure of collective action has frequently been mentioned as a reason why individual countries so far have not introduced prices on emissions. Yet, even without taking into account the negative external effects inflicted on other countries, there should be an incentive to put a price on emissions that internalizes the climate impact that a country exerts on itself (Barrett 1994; Carraro and Siniscalco 1993).[1] For instance, a game-theoretic analysis based on the numeric model MICA (Lessmann, Marschinski, and Edenhofer 2009) calibrated on different damage functions[2] employed in the literature reveals that in a Nash equilibrium in which countries strategically choose emission prices in a purely self-interested manner, India and China would – as identified by the largest estimates – implement carbon prices amounting to up to almost 40% and 25% of the optimal price respectively, while for the US and the EU the maximum values are up to 10% and slightly below 30%, respectively (see Figure 3). The large spread in estimates between regions can be explained by differences in regional abatement costs and regional climate impacts, as well as possibilities to

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[1] Suppose there a three a three countries, A ,B, and C, with marginal damages of 20,10 and 5 $/tCO_2$, respectively. According to the Samuelson rule, the socially optimal policy would then be a carbon price of 35$ in each country, internalizing all damages. Yet, without cooperation countries would not impose this price. However, if they act rationally, they would impose an emission price equal to their own marginal damages, i.e. they unilaterally would impose (differentiated) prices of 20,10, and 5$, respectively

[2] Damage functions are usually generated by fitting a cost function of a particular functional form (e.g. quadratic) to estimates from case studies for individual regions and economic sectors.

alleviate them through adaptation.[3] However, it should be also noted that there are large variations between estimates for any single regions. These are due to considerable model uncertainties related to (i) physical climatic changes, (ii) socio-economic impacts, and (iii) their monetary valuation (e.g. with regard to health). This large variation is not a particular to our study, but is a general feature of the literature assessing the ‘social cost of carbon’ (Tol 2009).

[Figure 3]

The transformation of the global energy system towards low-carbon technologies and energy efficiency enhancements triggered by carbon pricing could have economic benefits that exceed those of avoided climate change. More efficient resource use, technological innovation, and additional employment opportunities are hoped to increase economic performance by means of ‘Green Growth’ (UNEP 2011) and lay the foundation for a ‘Green Industrial Revolution’ (Stern 2009). These arguments imply that an energy transition would be desirable even without taking climate change into account. However, recent studies have pointed out that the alleged benefits in terms of energy efficiency improvements and employment are likely to be smaller than expected by optimistic assessments (Allcott and Greenstone 2012;' Borenstein 2012) and that a switch to low-carbon energy technologies does not entail the deep restructuring of economic activity and society witnessed during the industrial revolution (Demailly and Verley 2013). Nevertheless, even though emission reductions are probably not a ‘no-regret’ option by themselves, they very likely entail synergetic benefits by either triggering the use of negative cost energy efficiency options that would otherwise remain untapped due to behavioral or market barriers (Staub-Kaminski et al. 2014), or increased technology spill-overs to other economic sectors (Dechezlepretre, Martin, and Mohnen 2013).

Besides the impacts of climate change, there are other externalities that are positively correlated with GHG emissions, at least in a second-best setting in which not all associated policy objectives are

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[3] The high estimate of the carbon price for India is explained by high damages as well as high abatement costs. By contrast, Sub-Saharan Africa, which also exhibits high vulnerability to climate impacts, would implement a lower domestic carbon price due to lower marginal abatement costs.

optimally addressed by specific policy instruments (Lipsey and Lancaster 1956). For instance, according to McCollum et al. (2013) stringent GHG emission reductions would also improve air quality as a consequence of cleaner energy production, such that in 2030 the loss of 2–32 million disability adjusted life years would be prevented. A major uncertainty for policy design is that not only the material extent of these co-benefits, but also their economic valuation, is fraught with large uncertainties. Carrying out a review of the economic benefits of improved air quality from climate change mitigation in multiple countries, Nemet et al. (2010) find a range of US$ 2-196 per tCO_2 with a mean of US$49 per tCO_2 (with the highest co-benefits in developing countries). So, at least at the higher end of this range, these (domestic) co-benefits would be similar to – or even higher than – the (global) benefits of avoided climate impacts. Other co-benefits of climate change mitigation include reduced congestion, which would – as a consequence of reduced travel time – result in considerable economic benefits (Duranton and Turner 2011). For example, for the city of Beijing, Creutzig and He(2009) estimate that the social costs of congestion as well as those of air pollution both amounted to more than 3% of regional GDP in 2005. Other urban transport benefits include public health effects from increased physical activity and noise ambience (Creutzig, Mühlhoff, and Römer 2012; Woodcock et al. 2009). In addition, low-carbon energy technologies have been identified as promising options to provide energy access to the poorest members of society, especially for regions without connection to the electricity grid (Casillas and Kammen 2010). Henceforth, these policy objectives might be more important domestic motives for emission reductions than climate considerations, leading to a situation where multiple objectives are best addressed by multiple interacting policy instruments (Edenhofer et al. 2013). This is confirmed by case study evidence suggesting that for India, energy security considerations dominate the climate policy discourse (Dubash 2013), while for Vietnam increased resource efficiency appears to be the main objective of recently implemented Green Growth policies (Zimmer, Jakob, and Steckel 2015). Importantly, these types of benefits would unfold over much shorter timespans than those of climate change, and thus tend to align better with the priorities of policymakers.

II.4. Synthesis of unilateral incentives

We now provide in Figure 4 a tentative comparison of quantifiable incentives for domestic action, revenue generation, avoided climate damages, and co-benefit.. While the main purpose of this paper is to provide an overview of the principal motivations to implement an emission price rather than speculating about its precise value, this tentative comparison demonstrates the relevance of this framework by pointing to plausible quantitative magnitudes of non-climate incentives. Revenues from emission pricing (x-axis) are calculated as described in Figure 2 for an emission price of $30 in the year 2020, and avoided climate damages (y-axis) are median estimates from Figure 3. Regional co-benefits of reduced ozone and PM2.5 pollution (area of circles) are taken from West et al. (2013) who employ a global chemical transport model. As a conservative value, we use their results obtained for their lower bound estimate for the ‘statistical value for the loss of life’.

The results should be read as indicative, as substantial uncertainties, especially in avoided climate damages and to lesser degree in co-benefits, underlie the data. In addition, to comprehend the interplay between these motivations, they need to be assessed in a second-best framework à la Lipsey and Lancaster (1956), in which an economic distortion associated with one of the aspects simultaneously influences the emission price appropriate to target all others. That is, there are interaction effects between the different motivations, which – similar to the tax interaction effect identified in the double-dividend literature (see e.g. Goulder 2013) – may have a downward influence relative to the thought experiment case in which heterogenous tax rationales are merely added up. The hypothesis adopted in this paper is that – at least for a realistic set-up – each motivation included in the analysis results in an emission price above the one that would obtain if it were excluded, i.e. that its positive influence on the emission price is not over-compensated by a negative interaction effect (for an example of optimal internalization of co-benefits in an Pigouvian urban transport setting see Creutzig and He 2009). A more rigorous theoretical treatment and a quantification of the total into individual effects as well as their interaction require further analysis. In addition, most countries already apply an implicit emission price by means of e.g. fuel and energy taxes. For the OECD, these emission prices range from below zero (subsidies) to above 800 €/ton CO_2, with an average of approximately US$ 27 per ton of CO_2 (OECD 2013). These implicit prices might already capture or even exceed what is mandated by the motivations discussed in this paper. A comprehensive assessment would require the formalization, quantification, analysis of interaction as well as evaluation of the multiple rationales underpinning each of these policies. Our analysis should hence best be regarded as formalizing a framework that helps to correct inefficient choice of taxes and other public policies.

Nonetheless, a few tentative conclusions on world-region-specific policy agendas emerge from this synthesis. Most importantly, China would have an incentive to act on climate change from all three quantified dimensions, but most importantly in terms of co-effects in reduced air pollution and avoided climate damages. The equally populous India, in turn, would profit mostly from avoided climate damages, but less so from co-benefits and revenues. The incentive structure is different for OECD countries and Russia. The US and to lesser degree Russia and then the EU and Japan would mainly benefit from obtained revenues of domestic climate pricing.

[Figure 4]

Overall these results suggest that world regions could start with differentiated pricing reflecting their idiosyncratic incentives. In turn, as incentives are different even for approximately equal pricing levels, domestic instruments could be designed but also communicated in a way that incorporates these specific incentive structures. For example, the US could highlight the revenue effects, or the compensating reduction in other taxes (White House 2014). In turn, China could focus its mitigation efforts where these also reduce air pollution, e.g. by first mothballing old coal power plants close to metropolitan regions and tackling urban transport.

A few specific observations complicate the picture. First, the co-benefits from air pollution are surprisingly large with values of up to \$200/tCO_2 reported, higher than many estimates of the social costs of carbon. This could lead to the conclusion that climate change is only a secondary concern. Such a conclusion, however, is unwarranted for two reasons. First, the co-benefits correspond to direct physical benefits; they were not analyzed and calculated in systematic counterfactual analysis and hence do not reveal the opportunity costs of, for example, choosing climate mitigation action instead of direct tackling of air pollution measures (IPCC 2014, Chapter 3). In short, the numbers were not obtained on equal par and cannot be compared as such. Second, the climate damages could be understood as being conservative in so far as climate change involves many unknowns of which, obviously, the costs are not known, if they can be calculated at all (e.g. climate-change contributions to deteriorating health, civil wars and mass migrations). Nevertheless, this analysis reveals two crucial observations: first, as effects other than climate change mitigation need to be included in the calculation, the resulting emission price will in general differ from (and might even exceed) the avoided climate damages. Second, as already noted by Hourcade and Gilotte (2000), different country-specific incentives, due to e.g. different levels of pollution and different preferences, result in different emission prices for different regions.

A patchwork of differentiated pricing of GHG emissions could reflect local incentives but could also be globally inefficient. In fact, climate change economics has for long argued in favor of a globally uniform price on carbon in order to avoid leakages. This concern suggests a way forward to the interplay between domestic action and international negotiations. While domestically differentiated pricing schemes can, first of all, lead to rapid action, international negotiations can then focus on harmonizing and distribution issues, increasing effectiveness, efficiency and equity of the differentiated pricing scheme.

One often voiced concern against differentiated emission pricing is emission leakage. That is, the emission reductions achieved in one area could be at least partially offset by increases in other areas with lower prices by means of relocation of polluting industries (Copeland and Taylor 2004) or declining prices – and hence increased consumption elsewhere – of fossil fuels (Sinn 2008). Yet, recent studies suggest that this effect is likely too small to seriously undermine the effectiveness of unilateral climate measures. For instance, in a comparison of 12 computable general equilibrium models, Böhringer et al. (2012) find leakage rates (i.e. the fraction of emission reductions offset by an increase of emissions elsewhere) between 5% and 19%, with a mean value of 12%. Some have pointed out that leakage could even become negative (i.e. there could be inter-regional emission reduction effects from first movers) either due to technology spillovers (Bosetti et al. 2009), crowding out of 'dirty' capital stock (Carbone 2013; Baylis et al. 2013), induced inter-fuel substitution in other countries (Arroyo-Currás et al. 2013), or technology spill-overs that reduce other countries' abatement costs (Di Maria and Werf 2005). Finally, emission leakage can to a certain extent be alleviated by specific policy instruments, including free allocation of emission permits to energy-intensive, trade-exposed sectors (Fischer and Fox 2012) and trade measures (Jakob, Steckel, and Edenhofer 2014). For the latter, border tax adjustments and carbon tariffs, both of which impose a price on imports proportional to the amount of emissions generated in their production (Jakob, Marschinski, and Hübler 2013), as well as trade sanctions that pose an incentive to adopt cleaner technologies (Urpelainen 2013a; Lessmann, Marschinski, and Edenhofer 2009) are the most prominent instances.

Further, not only a price on emissions, but also the development of new technologies and learning effects that reduce the costs of existing technologies are crucial for the composition of technology portfolios and mitigation costs (Luderer et al. 2011). As argued above, a price on GHG emissions is essential to internalize the environmental externality. However, as there are additional market failures related to the development and diffusion of technologies, an emission price is not sufficient for cost-efficient climate change mitigation (Jaffe, Newell, and Stavins 2005), especially when learning-by doing can result in a lock-in of carbon-intensive technologies (Acemoglu et al. 2012; Kalkuhl, Edenhofer, and Lessmann 2012). For these reasons, emissions pricing needs to be complemented by technology policies, such as R&D subsidies, feed-in-tariffs, or renewable energy quotas, to address the corresponding market failures (Fischer and Newell 2008). Emissions pricing can constitute one potential source to provide the financial resources for these policies.

Finally, like any economic policy, emissions pricing creates winners and losers. Some studies have indicated that emissions pricing would be regressive, as poorer households spend larger shares of their incomes on energy (the ‘income uses’ effect; Grainger and Kolstad 2010). However, a more comprehensive analysis taking into account general equilibrium effects on factor rewards (such as interest on capital) finds a countervailing progressive effect (the ‘income sources’ effect Rausch, Metcalf, and Reilly 2011), which may cancel out the income uses effect. In any case, an emission tax or similar instrument can be adjusted to have a progressive distributional effect if either existing taxes are lowered in a manner benefitting low-income households or public goods are provided in a way that more than proportionally benefits poorer people (Rausch et al. 2010). A further consideration for the political feasibility of emission pricing concerns the potential resistance of powerful interest groups, such as industry lobbies. While tax exemptions – which remove the incentive conveyed by the price signal – are economically inefficient to compensate losers, free allocation of emission permits has been discussed as a viable alternative (Pizer 2002). As pointed out by Goulder (2013), if the US were to implement the emission reduction proposed under the Waxman-Markey bill, giving away about 13% of emission permits to energy-intensive industries would be sufficient to fully retain their profits. Under a tax system, a symmetric approach could be pursued by charging a tax not on actual emission, but on the difference to a defined threshold only, implying an infra-marginal tax exemption (Pezzey and Jotzo 2013).

III. International Negotiations

The previous sections have identified incentives for the unilateral adoption of a price on GHG emission that often operate on short-term time scales; they have argued that even without a global agreement to reduce GHG emissions several reasons exist for a government to impose an emission price above zero. While for most countries the motivations for unilateral action are unlikely to be sufficient to result in a domestic carbon price that is as high as the global socially optimal price, they might close a part of the gap between current emission prices in many world regions (see Figure 1) and open opportunities for incremental progress towards an effective global climate regime. Hence, this section first evaluates how unilateral action could promote international cooperation and identifies gaps in existing research. It then outlines possible structures for an international climate agreement based on unilateral carbon pricing policies.

III.1. Changing the Incentive Structure

It is an open question whether an international climate regime can resolve the pervasive free-riding dilemma in protecting the atmospheric commons and adopt a globally (at least roughly) uniform optimal GHG price (Edenhofer et al. 2013). But the benefits arising on the domestic level increase incentives for domestic carbon pricing. As optimal policy choices are interdependent (Hovi, Ward, and Grundig 2014) – implications for one country's carbon pricing influences the optimal carbon pricing scheme in other countries. It remains nonetheless unclear whether – and under which circumstances[4] – this interdependence can also promote international cooperation (Finus and Rübbelke 2013). This question has only relatively recently been addressed by an emerging literature on the issue of leadership, which identifies conditions under which unilateral action can promote action in other regions (Schwerhoff forthcoming). Some key insights from this literature are summarized below (see Table 1).

First, early action by some countries has the potential to enhance mitigation incentives for other countries and facilitate the implementation of a more ambitious international climate regime (compared to the case where countries do not implement domestically motivated carbon prices)

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[4] For instance, Hoel (1991) notes that in a game-theoretic setting, unilateral emission reductions could even increase global emissions, depending on the other players' reaction functions.

when mitigation costs decrease via technology spill-overs (Heal and Tarui 2010). If such spill-overs can reduce the costs of low-carbon technologies below those of traditional energy technologies, climate change mitigation is transformed from a prisoners' dilemma into a coordination game (with a carbon-intensive and a low-carbon equilibrium) (Heal 1999). This is particularly relevant for the case in which R&D costs decrease with the amount of R&D undertaken. Then, a green 'breakthrough' technology is more likely to be adopted and to increase the size of the coalition of countries contributing to the provision of the public good (Barrett 2006).[5]

Second, in a setting with asymmetric information, early action can be perceived as a signal of high willingness to cooperate in the future (Jakob and Lessmann 2012). If it credibly conveys the information that the early movers have a high willingness-to-pay for climate change mitigation but also face high abatement costs, other countries will expect to receive side-payments in the future, establishing an incentive to also introduce their own carbon pricing schemes. Hence, removing uncertainty with regards to the benefits of early movers can also help transform the underlying game from a prisoners' dilemma into a coordination game (Caparrós, Péreau, and Tazdaït 2004). It has further been demonstrated that, if abatement costs are correlated across countries and only known with uncertainty, early action by one can act as a credible signal for low overall abatement costs, giving rise to additional abatement by other countries (Brandt 2004). In a similar vein, reduced uncertainty with respect to costs and benefits of climate change mitigation has been shown to increase participation in and contributions to an international climate agreement (Kolstad 2007). From this perspective, early action can be regarded as contributing to social learning that entails knowledge transfer – similar to technology spill-overs – to other countries (Chatterji et al. 2013).[6] Likewise, it has been pointed out that building a regime to facilitate future cooperation can be an

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[5] However, there are also strategic incentives to delay investment in clean technologies in order to achieve a more favorable bargaining position in a future global agreement (Beccherle and Tirole 2011).

[6] Note that Konrad and Thum (2014) argue that - as it lowers the stakes of failing to agree for the other parties involved in the negotiation - early action can negatively affect the chance of reaching an agreement in a bargaining process.

important motivation for unilateral action and is identified by some authors as one of the main drivers of EU climate policy (Gupta and Ringius 2001).

Third, national policies are arguably not exclusively determined by cost-benefit considerations, but also influenced by notions of justice and fairness (Gardiner 2004). For instance, laboratory experiments indicate that individuals have a strong tendency to reciprocate cooperative behavior and reward others for the provision of a public good (Rand et al. 2009). Even though it is not straightforward to draw the analogy from individual behavior to national policies, it seems plausible that such normative preferences also play a role for international relations theory (Keohane 1984). As a consequence, one can conjecture that with a preference for equitable burden sharing, unilateral action by some countries could foster participation by other countries in an international climate agreement (Lange and Vogt 2003). For instance, even though developing nations might have considerable interest in climate change mitigation, their willingness to reduce their emissions likely depends to at least some degree on whether industrialized countries are perceived to contribute their 'fair share' to climate stabilization (Lange, Vogt, and Ziegler 2007). Hence, appropriately taking into account people's preference for cooperation in institutional design and gradually increasing commitments to create trust can promote collective action (Andreoni and Samuelson 2006).

Fourth, unilateral emission pricing policies possibly starting at moderate levels of ambition (and moderate economic and political risk) might facilitate incremental progress towards an ambitious international regime by creating constituencies and changing the landscape of the political economy. As the introduction of emission pricing in some countries could alleviate leakage and competitiveness concerns and hence ease the resistance of energy-intensive industries in other countries (especially those perceiving each other as direct economic competitors), unilateral action has the potential to trigger further participation in an international climate treaty[7]. Furthermore, providing an

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[7] A similar mechanism that conceives international agreements as 'two-level games' (Putnam 1988), in which actions in one country influence the domestic political economy in other countries, has been demonstrated for the 'domino-theory' of trade liberalization (Baldwin 1993).

institutional framework that both identifies areas where international climate finance would be particularly useful for a country given its specific circumstances (co-benefits) and creates the policies that might be modified contingent upon the reception of international climate finance (e.g. increasing domestic carbon prices, or increasing stringency of technology policies, perhaps including modified compensation measures for targeted societal groups financed by international climate finance) (Urpelainen 2013).

[Table 1]

Therefore, unilateral policies could be regarded as a key building block of a 'polycentric climate regime' that takes into account the benefits of climate change mitigation arising in different dimensions and at different levels of governance in decentralized and partially coordinated policies (Ostrom 2010). This is exemplified by the mutual reinforcement of interests of member states, the European Commission, and the European Parliament that resulted in the formulation of EU climate policies (Schreurs and Tiberghien 2007). Furthermore, policy coordination opens avenues to extend carbon pricing through 'issue linkage', for instance by negotiating environmental provisions jointly with technology cooperation (Lessmann and Edenhofer 2011) or trade agreements (Baghdadi, Martinez-Zarzoso, and Zitouna 2013).[8]

III.2. Possible Shapes of a Hybrid International Climate Agreement

Several recent contributions have assessed hybrid regimes in which bottom-up incentives are coordinated in an international framework. Rietig (2014) argues that climate negotiations should, instead of focusing on legally binding quantitative reduction commitments, be organized as open fora to exchange bottom-up pledges and share experiences with regard to policy design and effectiveness. Edenhofer et al. (2013) propose a hybrid and dynamic architecture for an international

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[8] Likewise, trade sanctions could be introduced as a punishment mechanism to deter free-riders (Lessmann, Marschinski, and Edenhofer 2009).

climate regime emerging from The Durban Platform for Enhanced Action. Such a regime might emerge from a bottom-up approach based on decentralized country policy pledges, in particular with regard to domestic carbon prices. Centralized top-down coordination functions, such as monitoring of emissions, peer-review of commitments, or regulation of carbon markets could then be undertaken within existing or newly created UNFCCC mechanisms (Dubash and Rajamani 2010). Interstate institutions could be complemented by more decentralized transnational policy coordination allowing sub-state actors and civil society to advance the climate policy debate and circumvent lack of ambition on the national level (Abbott 2012). Such coordination mechanisms could also serve as platforms to coordinate domestic policies, e.g. for the linking of regional or national emission trading systems (as currently pursued by California and Quebec (Ranson and Stavins 2014) or joint R&D efforts (de Coninck et al. 2008).

[Figure 5]

To enable flexibility in accommodating diverging policy preferences, it seems reasonable and in fact unavoidable to allow countries committing to a broad range of policy packages, such as carbon pricing, emission reduction targets, intensity targets, support for renewable energy technologies and R&D, or energy efficiency programs, instead of focusing rigorously on negotiating country-level long-term ‘targets and timetables’ or ‘emission budgets’, which have been the focus of UNFCCC negotiations over the last decades (Victor 2011).

One focus of negotiations could be on increasingly harmonizing domestic GHG prices across countries (Cooper 2007; Nordhaus 2007; Weitzman 2013; Morris, McKibbin, and Wilcoxen 2013). This would ensure efficiency of the global mitigation effort by harmonizing the level of ambition across countries, and would address concerns over competitiveness and carbon leakage arising in a world of strongly asymmetric GHG prices (see below). Countries that have adopted cap-and-trade systems which regulate the quantity of emissions rather than their price might consider the implementation of minimum and maximum prices (so-called price collars; Fell et al. 2012). This approach has been adopted in the ETS recently established in California and Quebec as well as in the Regional Greenhouse Gas Initiative (RGGI) scheme and does not only offer more stable investment environments for private firms and enhanced certainty over public finance revenues from permit auctioning, but would also enable the coordination of minimum GHG prices across world regions. Such international coordination might involve precisely defined conditionality of domestic carbon pricing schedules contingent of other regions' implementation of certain carbon price levels (and potentially other policy reforms, such as the phase-out of fossil fuel subsidies). To address differences in the willingness or ability to impose carbon prices in line with a global target price range, transfer payments (Chichilnisky and Heal 1994) channeled through e.g. the Green Climate Fund (gcfund.org) might be conceived.

Centralized functions of the formal climate regime might include technical support in devising domestic policy packages, collecting and aggregating pledges in terms of their combined outcomes in order to inform negotiations over enhancing the collective level of ambition, providing transparent monitoring, reporting and verification (MRV) of policy packages to assure countries they do not become victims to free-riding (Aldy and Pizer 2014), and financial as well as technological country support (see Figure 5). Such a regime could be rendered dynamic by enabling adjustments to domestic policy packages as well as international coordination functions over time, with countries increasing their efforts conditional on increased ambition by other countries (Victor 2011).

IV. Conclusions

This article demonstrates that even in the absence of a global agreement on climate change mitigation, every country has a plausible reason to impose an emission price above zero. First, emission pricing would be mandated to generate revenues for the government budget that enables decreasing other distortionary taxes, as well-established in the double-dividend literature. Second, an emissions price may improve macroeconomic efficiency by reducing tax competition and correcting investment behavior, and additional revenues from emission pricing could help to promote human well-being by financing the provision of public infrastructure and contribute to meeting financing needs for mitigation and adaptation. Third, even if countries do not internalize the negative effects of their emission on others, they would still put a price on their emissions equal to the marginal damage they exert on themselves. Furthermore, important co-benefits in the form of e.g. reduced air pollution, less congestion, increased energy access and energy security as well as improved resource efficiency could be at least as important as the benefits of climate change mitigation. We also show that the above incentives can differ rather widely across countries: while for China avoided climate damages and co-benefits of reduced air pollution appear to be the main motivation for emission pricing, for the US generating public revenue is perhaps of highest importance, and for the EU all three incentives are of intermediate importance.

These unilateral motivations are unlikely to be sufficient to achieve the globally optimal emission price. However, they could – by closing part of the ‘emission price gap’ – pave the way towards a global climate agreement and – by avoiding lock-in of carbon-intensive technologies and infrastructures – keep the option of achieving ambitious climate change mitigation in the future open. Importantly, many of these positive effects operate on much shorter timescales than climate change, thus providing incentives for their adoption by policymakers operating under short-term political constraints.

We have proposed that unilateral emission prices in different countries could form the building blocks of a ‘polycentric climate regime’. These domestic policies could be coordinated on the international level by a ‘hybrid agreement’ allowing coordination of a variety of policy packages instead of focusing on a rigid targets and timetables approach to emission reductions.[9] Such an agreement could be gradually scaled up over time by countries pledging to increase their effort conditional on policy support or more ambitious targets in other countries. Regardless of the

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[9] However, quantitative assessments of emission limits required to achieve a certain reduction target, such as carbon budgets, may provide useful focal points for negotiations.

underlying motivation for adopting domestic GHG emission reduction policies, the agreement structure outlined above would provide the required flexibility to coordinate national policies into an international framework. In particular, as the motivations appeal to different interest groups on short-term time horizons they offer an opportunity for policy makers to assemble suitable societal coalitions to garner political support for GHG emission pricing. In this context, emissions pricing can increase the political feasibility of emission reduction policies: even though non-market regulatory policies (such as efficiency standards) may appear politically attractive by not making mitigation costs explicit, the cost efficiency of price based policies[10] could potentially provide a more important political rationale. Finally, besides reducing current emissions, emission pricing could also have important long-term consequences by lowering future mitigation costs and hence making a policy reversal by successor governments less likely (Urpelainen 2011).

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[10] Parry et al. (2014) estimate that for the US energy efficiency standards "when viewed as substitutes, these standards forgo 60 percent or more of the potential welfare gains from corresponding pricing policies" (p. 104).

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Figures

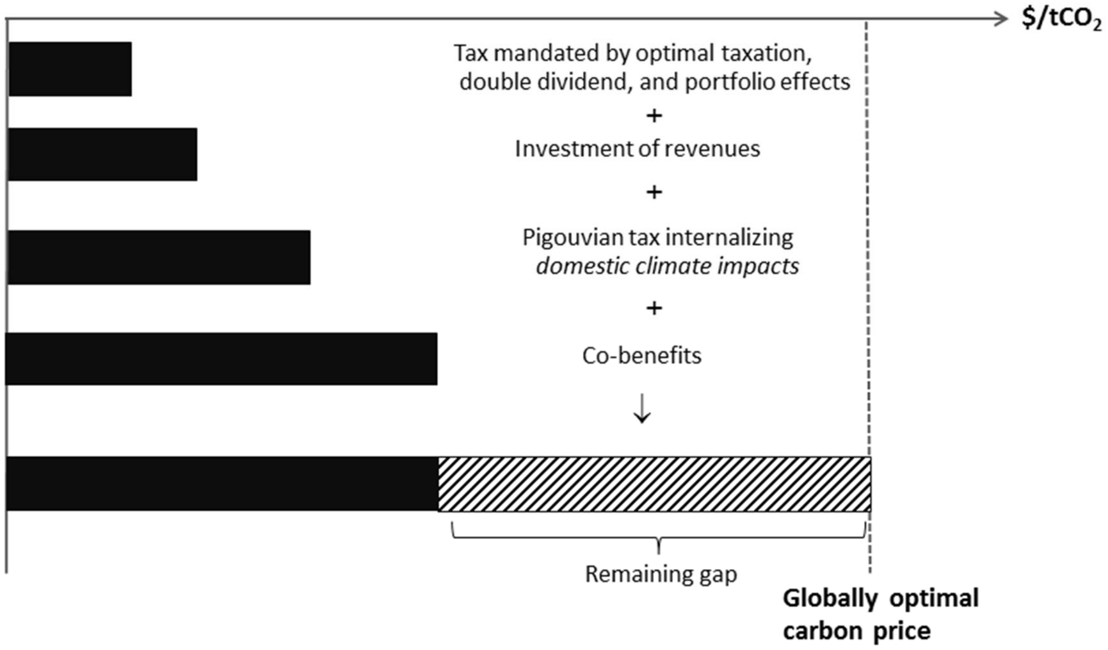

Figure 1: Incentives to introduce unilateral emission prices and their relationship to international negotiations.

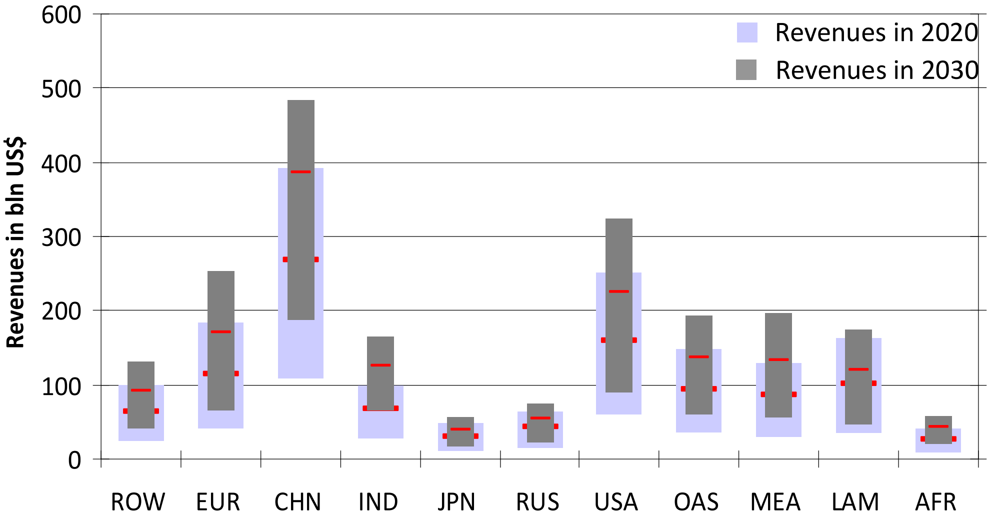

Figure 2: Amount of annual revenues in bln US$ for different regions for different tax levels in 2020 (light grey) and 2030 (dark grey). Tax levels are set to $10 (lower bound of bars), $30 (red line) and $50 (upper bound of bars) per ton of CO_2, respectively in 2020, increasing by 5% per year. All mitigation technologies are assumed to be available. Scenarios are calculated using the ReMIND model (Leimbach et al. 2010) as described in (Luderer et al. 2013). See SI for details.

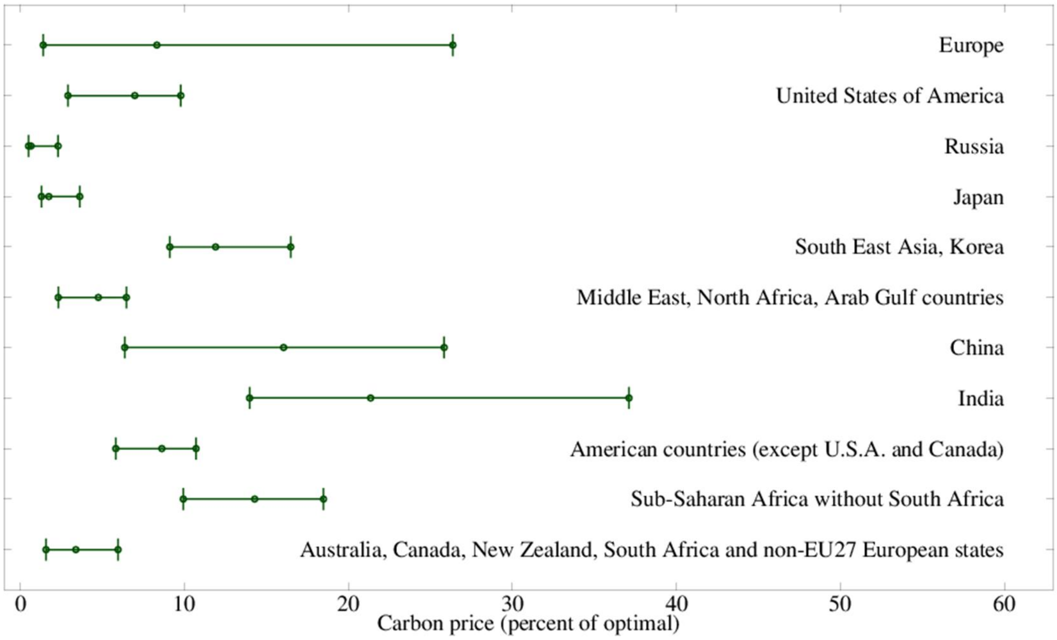

Figure 3: Unilateral carbon prices calculated with the MICA model based on different damages functions as used in the RICE (Nordhaus and Boyer 1999)) and STACO (Dellink et al. 2004) models, expressed in terms of percentage of the optimal global carbon price calculated by MICA. For details, see SI.

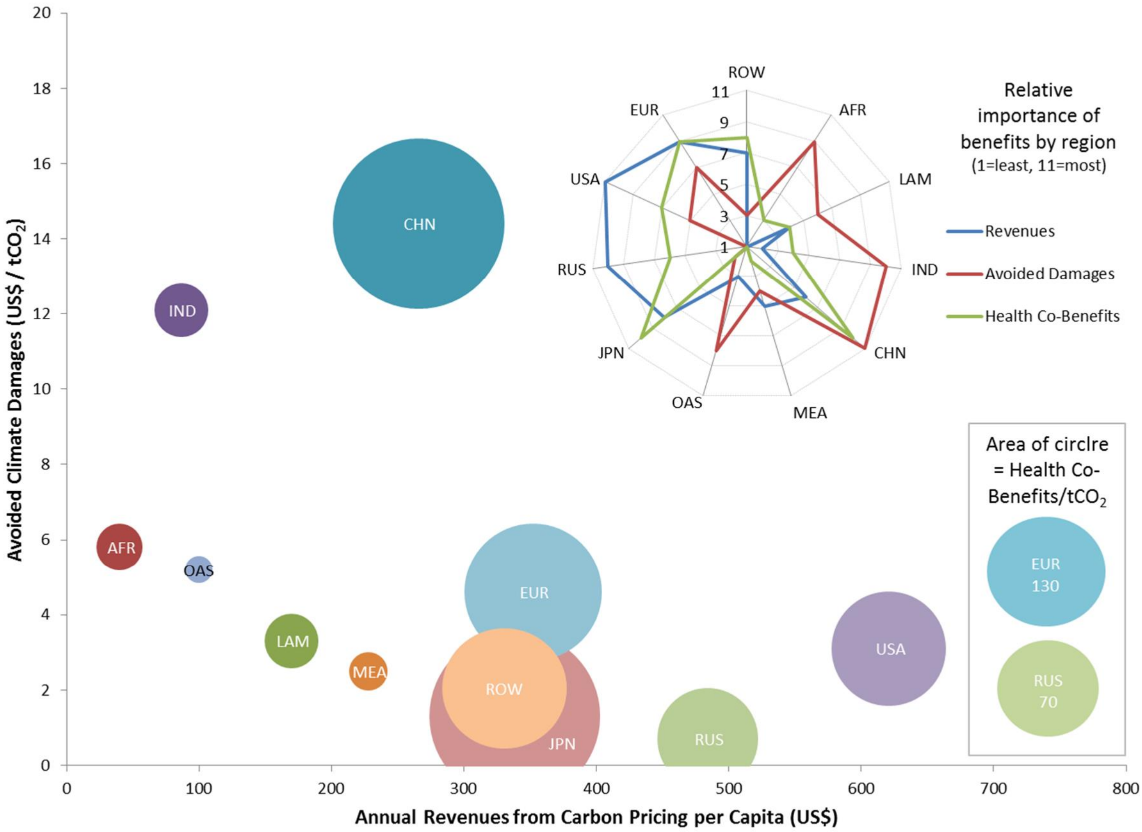

Figure 4: Summary of incentives for unilateral carbon pricing by region: annual per capita revenues from a carbon price of USD 30/tCO_2 (x-axis), avoided climate damages per avoided tCO_2 (y-axis) as well as health co-benefits (area of circles). The upper right inlay ranks regions according to the size of benefits in these three dimensions. Data for revenues and avoided climate damages and were obtained from the calculations used for Figure 2 and Figure 3, respectively. Data for health co-benefits are from West et al. (2013). See SI for details.

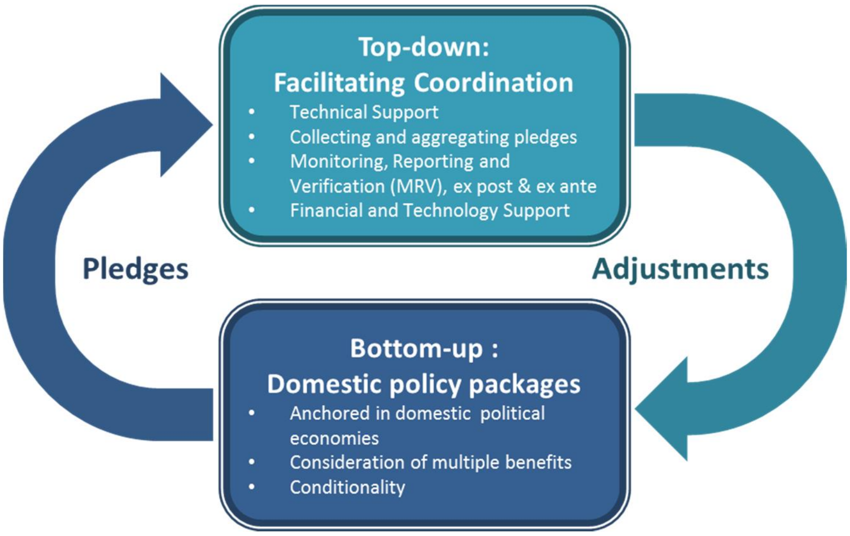

Figure 5: Structure of a dynamic hybrid climate regime (based on Edenhofer, et al. 2013).

Tables

Channel	**Effects**
Technology spill-overs	Reducing abatement costs in other countries (Heal 1999, Heal and Tarui 2010), transform climate change mitigation in a coordination game in case of a ‘breakthrough technology’ (Barrett 2006)
Social learning and signaling	Reduce uncertainty over benefits and/or abatement costs (Brandt 2004, Kolstad 2007), signal high willingness to provide side-payments in future agreement (Caparrós et al. 2004, Jakob and Lessmann 2012)
Reciprocity	Preference for equitable burden sharing (Lange and Vogt 2003, Lange et al. 2007), preference for cooperative behavior (Andreoni and Samuelson 2006)
Political economy and institutions	Easing political opposition (Putnam 1988), creating constituencies (Urpelainen 2013), building institution (Keohane 1984, Ostrom 2010)

Table 1: Channels through which unilateral action could promote collective action and main effects identified in the literature.