NOTA DI LAVORO

97.2013

Leadership and International Climate Cooperation

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Climate Change and Sustainable Development
Series Editor: Carlo Carraro

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Summary

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Keywords: Climate Change, Leadership, Public Good Provision

JEL Classification: H41, O33, Q54

I thank Jérôme Hilaire, Michael Pahle and participants of the workshop "Towards a New Climate Politics" at Zeppelin University, Friedrichshafen, for helpful discussions.

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Leadership and International Climate Cooperation

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September 17, 2013

Abstract

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1 Introduction

Years of research in climate physics, policy options and sustainable technologies have revealed a rather clear picture that climate change should be mitigated and how this can be achieved. After a large number of failed climate summits, however, there is still no clear path for achieving the required cooperation for providing this global public good. In this paper I describe a range of mechanisms in favor of unilateral action or leadership. A single country or region implementing effective climate policy may provoke a free-rider effect by other countries, meaning that they reduce their own efforts. But this negative mechanism is countered by a number of mechanisms that would lead other countries to follow suit and step up their climate mitigation efforts. Taken together, it appears that the potential of leadership as a means of achieving cooperation on climate change is hitherto underestimated.

I take climate mitigation to be a public good and consider leadership in the form of leading by example. Leadership will thus take the form of contributing to the public good by unilaterally implementing climate change mitigation. Within this frame I identify three categories of positive reaction mechanisms. The first is a behavioral reaction. Out of a sense of fairness, followers may want to reduce inequity. A leader's action may establish a new norm or modify the existing norm, so that followers which are guided by norms to some extend would step up their efforts. Second, the action may help overcoming information asymmetries. If lack of knowledge on preferences or the relative value of avoiding climate change blocks cooperation, then a leader's action my indirectly provide this knowledge. Third, the followers could benefit directly from the leader's pioneering actions. This improved cost benefit ratio may change the assessment of other nations in favor of mitigation. By starting to mitigate, the leader engages in a learning process from which potential followers benefit. These benefits include sustainable technology, successful policies and reduced uncertainty about the cost of mitigation.

These three effects are based on abstract economic reasoning of which positive reaction mechanisms leadership might entail. However, there are also some important insights on leadership in the politically focused literature on alternatives to the failing attempt of reaching a global climate agreement. Some authors favor a bottom-up approach or a new approach termed "dynamic climate governance". Both of these rely to some extend on leadership. The mechanism of leadership to be exploited in these approaches are technology and policy

development as well as political "crystallization". This term refers to a group of nations intentionally setting up a "seed" of climate cooperators with the intention of making it grow by letting additional members join.

Leadership can be understood in different ways. It is often associated with the authority to coerce others in some way. Since countries' ability for coercing other countries is quite limited we follow Hermalin (1998) and define a leader as someone who sets an example and relies on voluntary leadership. The leader's reliance on the followers can go so far that his action as such may not be beneficial for himself. He may, however, anticipate that others will follow him and that he benefits from that. His decision to take the first step may thus be based on a strategic assessment of the reaction of the followers. This is a common feature to all mechanisms above and is described in Potters et al. (2005). Given the uncertainties and lacking information of the leader it may even be that leading is profitable only in expectation.

A first strand of related literature is the traditional economic point of view on unilateral action as described in the theoretical analysis in Hoel (1991). It explicitly assumes that countries are purely dictated by their self interest. In this setting any unilateral contribution to the public good will provoke a free rider effect. Other countries benefit from the unilateral action and reduce their own contributions. Using game theoretic coalitional stability analysis in a numerical integrated assessment model, Bréchet et al. (2010) estimates quantitative responses of specific major players to the policy leadership of the EU. They find that the strategic policy reaction of other countries is very limited. Only when countries are connected through emissions trading can a noteworthy effect be provoked through an increased permit price. In contrast to this literature, I relax the assumptions that countries are motivated by narrow self-interest, that information are complete and that nothing can be learned by implementing climate policy. Allowing for more complex preferences, asymmetric information and knowledge transfer from the leader to potential followers makes the positive effects listed above possible.

A related argument on the benefits of environmental policy even in the absence of a climate agreement is the Porter Hypothesis, developed in Porter and Linde (1995) and refined among others in Xepapadeas and de Zeeuw (1999), Mohr (2002) and André et al. (2009). According to this hypothesis, environmental policy induces innovations which increase the competitiveness of the policy area to such an extend that it overcompensates the cost of adapting to the policy. In this approach, the direct gain for the leader is central and the

provision of the public good marginal. In the approach taken in this paper it is the other way around. It relies on the strategic response of other countries to adopt an ambitious environmental policy as well.

A third strand of related literature is the point of view of political science on climate leadership. Meijerink and Stiller (2013) and Skodvin and Andresen (2006) for example analyze the political requirements for and characteristics of leadership on climate change. Schreurs and Tiberghien (2007) argue that a few individual EU member states played an essential role in the EU's climate policy. Afionis et al. (2012) shows that the EU as a whole took a leadership role in international climate negotiations. In contrast to this leadership in negotiations, this paper is concerned with leading by example through unilateral implementation of effective climate policy.

The remaining sections follow the categories identified above. Section 2 describes the behavioral aspects of leadership in climate mitigation. Section 3 discusses the role of leadership in breaking the deadlock created by asymmetric information on climate change. Section 4 is concerned with the tangible benefits of mitigation leadership for the followers. Section 5 investigates the leadership effects identified by the literature on alternative to a global climate agreement. Section 6 concludes.

2 Behavioral Aspects of Leadership

As we will discuss below, experimental evidence on economic decision-making has revealed that human behavior is guided to some extend by concepts like fairness and norms. In certain settings at least, self-interest is thus not the only motivation for decisions. Based on the evidence, theories have been developed which define preferences and utility functions in a way that can explain apparently altruistic behavior in a broad range of experiments. When applied to experiments with a leader they can explain why leadership makes a difference: Other players observe the leader's decision and may adjust their own contribution towards that of the leader.

There is no immediate reason why behavioral phenomena observed in the laboratory should guide the behavior of nations as well. However, some indication can be found that the interaction of governments on climate change is not only motivated by direct self-interest. First, we do observe governments cooperating on projects where a strict selfish maximization would require free-riding. The Kyoto protocol as an example highlights that this cooperation

is far from being fully efficient in providing the public good. It does indicate, however, that governments are not the narrow payoff-maximizers postulated in models like Hoel (1991) and Varian (1994), where unilateral action does not achieve an improvement in public good provision. Second, equity and fairness is stated as an important aspect in negotiations on climate change and can be found in the declarations of climate negotiations. Lange et al. (2007) provides quantitative evidence on how important these statements are in climate negotiations. Third, the electorate is made up of partly altruistic individuals and governments may be responsive to that. Lange and Vogt (2003) quote "The Hague Mandate", of the Climate Action Network (CAN), which found broad support by international organizations and demands a fair distribution of emission rights.

There are examples that leadership has triggered environmental protection and an indication that this has to some extent been achieved since the leader established a new norm. Bodansky (2000) gives the examples of a unilateral action taken by Great Britain in 1967 which led to the International Convention Relating to Intervention on the High Seas in Cases of Oil Pollution Casualties and of action taken by the United States in 1970 which led to the International Convention for the Prevention of Pollution from Ships (MARPOL).

Given the advances in behavioral economics and the importance of fairness and social norms, Brekke and Johansson-Stenman (2008) considers it "surprising that behavioral economics has had so little influence on the economics of climate". This section of the paper is thus written in the tradition of papers which, like Hasson et al. (2010) "believe that the behavior of individuals revealed in the lab context can be used as a basis for understanding and analyzing key factors that underlie decision making on mitigation and adaptation on the country level", which also includes Lange and Vogt (2003), Lange (2006), Johansson-Stenman and Konow (2010) and Barrett and Dannenberg (2012).

2.1 Theoretical Concepts

Contrary to the theoretical predictions in Hoel (1991) and Varian (1994) there is a number of public good experiments with the basic finding that the provision of public goods is more efficient when there is a leader. This is found when comparing two settings. In the first, all participants contribute simultaneously. In the second, there is one participant making a contribution first. The first contribution can be observed by the other participants before they make their contributions. It usually turns out that contributions in the second case are

higher than in the first case. These results seem at odds with simple explanations of rational self-interest. Two theoretical approaches have been proposed as an explanation.

The first explanation is a preference for fairness, equity and reciprocity. In this explanation the followers adapt their own contribution to that of the leader out of a desire to behave fairly towards him. Fehr and Schmidt (1999) define fairness as inequity aversion, meaning that people "are willing to give up some material payoff to move in the direction of more equitable outcomes". The paper argues that the assumption that a fraction of people is motivated by fairness explains a wide range of apparently contradictory evidence on whether or not fairness considerations are an important motive. Similarly looking for a consistent pattern in disparate laboratory observations, Bolton and Ockenfels (2000) propose a model where "people are motivated by both their pecuniary payoff and their relative payoff standing". Following a proposition in Rabin (1993) Falk et al. (2008) show that in addition to the preference on fair outcomes, *fairness intentions* matter.

The second explanation is that of imitation and social norms. In this explanation, the followers observe the leader's contribution and either imitate his contribution or infer information from it about a social norm on the size of contributions. Imitation has been explored by evolutionary game theory. As Mailath (1998) points out, successful behavior becomes more prevalent not only because of selection pressure, but also through imitation. Imitation has evolved since it accelerates the learning process towards more successful behavior. According to Fehr and Fischbacher (2004), norms have been crucial in the development of the high degree of cooperation which distinguishes humans from other animals. Norm enforcement is driven by the availability of sanctions as well as non-selfish motives. Norms and imitation are grouped into one since they both rely on evolved patterns of behavior which may violate the two "heroic assumptions" of neoclassical economics, maximization and consistency, as Mailath (1998) put it.

2.2 Experimental Evidence

An experiment designed to test leadership in reducing emissions is provided in Moxnes and Van der Heijden (2003). Groups with a leader invest on average 13% more than groups without a leader. The costs of leadership, however, are not fully recovered by the leader. This means that the leader's action improves efficiency, but he doesn't benefit from this to the extend to which he increased his contribution compared to the case of simultaneous

contributions.

Moxnes and Van der Heijden (2003) is an early example for the standard result of leadership in public good experiments, which is described here since it was framed as a game on climate change. Since then, a number of authors have shed more light on why and how this result arises. Some of these results will be described in the remainder of this subsection. It remains a challenge, however, to identify the relative importance of the theoretical effects described above, fairness and norms.

Following the basic result, the experiments were refined in order to understand why leadership improves efficiency and in which framework it works best. Coats et al. (2009) test the hypothesis that leadership serves as a coordination device by contrasting it to games with refund rules. The refund rule means that the public good can only be provided when a threshold is reached and pledged funds are returned otherwise. They find that for a given refund role, provision of the public good is always more efficient in the sequential structure. The refund on the other hand increases efficiency only in the case of simultaneous contributions.

Some progress has been made on what exactly it is in a leadership contribution, which the other players honor by increasing their own contribution. Glöckner et al. (2011) investigates the role of sacrifice in leadership and thus distinguish between the "input" given by the leader and the "output" received by the other players. A sacrifice is a contribution which is not profitable if it is not followed. The paper finds that sacrifice has an important role in motivating second-movers to make a contribution to the public good. This confirms the finding of Falk et al. (2008) that intentions of cooperation (the input) matter and not only outcomes (the output). Reciprocity thus not only depends on the amount of the contribution to the public good, but also on the degree of self-sacrifice related to it. Contributions which are not "painful" are not honored as much.

Fairness as a motive for action by other players is undermined when it becomes less clear what a fair solution is. Levati et al. (2007) considers the role of heterogeneity in endowments. Leadership increases contributions both with heterogenous and with homogenous endowments. The effect, however, is weaker in the case of heterogenous endowments and weaker still when the heterogeneity is paired with incomplete information on endowments.

Whether social norms play a role when followers adapt their contribution when they can see what a leader does is the subject of Rege and Telle (2004). They find that cooperation is increased when the identity of contributors is revealed, thus making it public how the

individuals behaves. As an explanation for this effect, the authors suggest a preference for social approval. This preferences has been conjectured by Akerlof (1980) and others.

Some authors take the effect of leadership as a starting point and aim at improving further on it by finding out under which conditions leadership is the most effective. Güth et al. (2007) test whether voting for a leader could be a way of self-organizing effectively. When given this option only 40 % of groups make use of it. This is in line with results from Vyrastekova and Van Soest (2003), who find that resource management improves efficiency, but that in less than half of the cases a majority votes in favor of installing management. This shows that voting to have a leader is a form of endogenous leadership, which does not function in many cases.

A simpler mechanism than voting turns out to be more effective. In Rivas and Sutter (2011) one of the participants can simply volunteer leadership by setting an example. Groups in which leadership is voluntary make much higher contributions than groups where leadership is enforced exogenously. Voluntary leadership is compared to exogenously enforced leadership as well as groups without leadership, that is where all group members contribute simultaneously. About a quarter of subjects are willing to volunteer as leaders. Another result is that leaders contribute significantly more than followers. A difference between voluntary and exogenous leadership may be that in voluntary leadership, the most generous individuals become leaders. Another possible explanation is that there is more reciprocation when leadership is voluntary.

But in addition to how the leader is determined it is important who leads. Varian (1994) theoretically considers the case of an exogenous move order in public good provision and finds that it can lead to detrimental outcomes when the player with a high valuation for the public good moves first and commits to free-riding. Gächter et al. (2010) finds evidence for this. The apparent contradiction to Güth et al. (2007) seems to be explained by the following two differences in the setup. In Gächter et al. (2010) the returns from the public good vary across players and only two players are playing instead of the four in Güth et al. (2007). Nevertheless, Gächter et al. (2010) find that contributions are more even than would be expected from theory. The reason is that second-movers are willing to punish a first mover, a behavioral reaction which weakens the prediction by Varian (1994).

The behavior of subjects in Nosenzo and Sefton (2011) indicates that they consider it destructive when the player with the high valuation moves first. When the timing of contri-

butions is endogenous, this move order is avoided since there is no advantage to committing to be a free rider.

2.3 Relevance for Climate Change Mitigation Policy

Climate change mitigation is a particular "game" of public good provision. Actors cannot commit to giving only once, the game is played with a large number of players, contributions require genuine sacrifice, endowments and payoffs are heterogenous and leadership is endogenous as well as voluntary. Given the evidence above, we can draw conclusions on which aspects may influence the efficiency of leadership through unilateral action in positive or negative ways.

A crucial feature in explaining why leadership may be less efficient than simultaneous contributions in Varian (1994) is that each player can only contribute once. This is imposed by the structure of the game and implies that the leader can credibly commit to contributing no more than the initial contribution. Since nations cannot credibly commit to a contribution program, Varian (1994) seems not relevant for the climate context.

But even when the order of contributions is fixed by the game design, leadership increases efficiency in many cases as seen above. Gächter et al. (2010) is an exception. No explanation is offered for the causes of the exception, but it appears to be due to the particular game design with differential payoffs and only two players involved. The limitation to two players could be a crucial feature since a follower willing to punish a free-riding leader may not do so out of consideration for his fellow followers.

The results of Coats et al. (2009) point to leadership acting as a coordination mechanism, which can fulfill the same role as other mechanism like the refund rule. This can be understood in the context of Cooper et al. (1996), Watabe et al. (1996) and Hayashi et al. (1999) which find that cooperation is generally conditional. Leadership would thus work as a technique of channeling a conditional willingness for cooperation and fairness. In the climate context a leader nation could thus convince conditional cooperators among the other nations that there contribution is reciprocated.

Since climate change mitigation cannot be obtained without a certain degree of "self-sacrifice" in the form of economic costs, there is no danger of followers doubting the fairness intention of the leader. The "false" leadership analyzed in Glöckner et al. (2011) thus seems to be no threat to the effectiveness of leadership.

The result in Levati et al. (2007) that leadership is less effective when endowments are heterogenous is aggravated when information about endowments are incomplete. This may amount to an effect similar to the one in Glöckner et al. (2011) that leadership is not successful when it doesn't involve sacrifice since followers may suspect that the leader is not contributing a significant part of his endowments. The strong heterogeneity of "endowments" among nations may thus work against the effect of leadership, in particular when the leader's contribution is relatively small.

On the contrary, leadership on climate change mitigation is necessarily endogenous and voluntary. Given the evidence in Güth et al. (2007) and Rivas and Sutter (2011), this should have a positive effect since it demonstrates an intrinsic motivation to contribute to the public good.

3 Asymmetric Information

Section 2 can be seen as treating the question to which degree people cooperate and behave altruistically and how leadership can work in coordinating this cooperation. We now assume that there is a certain willingness to cooperate and allow information to be asymmetric. The asymmetric information might hinder cooperation so that outcomes are much less efficient than they would be under full information. In this situation leadership can transmit crucial information in a credible way and thus facilitate cooperation.

Even in the age of unprecedented transparency and very advanced technology, some kind of information could only be transferable through cost-intensive action. The prime example for this is preferences. The degree of importance a government attaches to a public good project like climate change mitigation is difficult to credibly convey verbally. Similarly, governments may have different quality of information on the value of the public good. A fear of manipulation could sabotage an otherwise straightforward way of transferring this information.

3.1 Theoretical Concepts

First we assume that the nature of the public good is known, but that the players have different valuations for it and that this valuation is private information. There is no incentive to reveal the own preference truthfully, since a player with a low preference for the public good could pretend to have a high valuation and thus induce a high contribution from the

other players. The only way of credibly conveying a signal is thus via an expensive action which would not be rational for a player with a low preference.

Jakob and Lessmann (2012) work directly on signaling in the context of international environmental agreements. When no international environmental agreement can be implemented due to asymmetric information, unilateral early action can signal the sender's type. Unilateral action is thus a means of credibly transmitting information to other countries.

Now consider the opposite case, where it is known how much players value a given public good, but the quality of the public good is not common knowledge. Hermalin (1998) points out the strategic difficulty of transmitting information credibly in this case. A leader must convince his followers that he is transmitting the correct information and is not misleading them. Contrary to authority, a leader cannot coerce his (potential) followers and must thus induce them to follow voluntarily. The leader can use sacrifice and leading by example to signal that an activity is worth something. In leading by example the leader shows through his own activity that it is worth it.

Hermalin (2007) follows up on Hermalin (1998) by extending the framework to a repeated game. This allows for the leader to build up credibility which will facilitate the communication.

Vesterlund (2003) explains theoretically why fundraisers announce contributions even though previous theory predicts that contributions are higher when no information on other contributions are available. The crucial new feature is imperfect information on the quality of the charity. Announcements of early contributions reveal the quality of the charity and thus motivate further contributions. The result from Varian (1994) that sequential moves are destructive is thus shown to rely on the first contributor being able to commit to giving only once.

Andreoni (2006) extends Vesterlund (2003) by assuming that the public good can not only take two values (good or bad), but several. This creates the additional difficulty that the initial contribution could be understood as a strategic manipulation to support a mediocre project. The initial contribution thus has to be exceptionally large in order to be credible.

3.2 Experimental Evidence

The situation with an unknown quality of the public good as suggested by Hermalin (1998) and Andreoni (2006) has been tested experimentally.

Potters et al. (2005) investigate the sequence of contributions to a public good when some contributors are informed about the value of the public good and others are not. They show that when the informed player moves first to make his contribution, the followers mimic the action of the leader. Anticipating the followers actions, the leader chooses to contribute to the public good when it is efficient to do so.

There could be various reasons for the information asymmetry such as particular skills or inside information. The initial donation thus has the important role of conveying information to those less informed. Depending on the nature of the public good and the quality of the leader's information, the followers may be able to infer the exact value of the public good or a range of possible values. The result from sequential moves can be compared to simultaneous moves. Theoretically, the sequential move can be expected to be more efficient. This is indeed found in one of the experiments.

Importantly, it makes a difference if the sequence of moves is determined endogenously or exogenously. When moving sequentially has been mutually decided by the players involved, the result is more efficient. The joint decision reassures players that they understand and appreciate the gains from sequential moves.

The exact role of signaling in leadership remains to be explored further. Potters et al. (2007) provide some indication on the quantitative importance. They follow up on Potters et al. (2005) with an attempt to distinguish between the role of leadership in signaling and the behavioral explanations from Section 2. By comparing experiments with full information to those with asymmetric information, they find that the leadership effect is mainly driven by signaling. The results of Glöckner et al. (2011) can also be understood as confirming the role of information transmission in leadership. When the contribution of the leader is not linked to a sacrifice the informational contend of the action is lower.

3.3 Relevance for Climate Change Mitigation Policy

Asymmetric information clearly plays a central role in climate mitigation. Governments do not know how much other nations value it and it also appears quite plausible that they are informed to different degrees on the importance of it. The interaction of contributing is repeated and the quality of the public good can take a continuum of values. A signal on the importance of climate mitigation is likely not to bring full information, but only to reduce the degree of uncertainty.

A leader on climate change could thus break an informational deadlock by signaling both his own high preference for mitigation and his knowledge about the value of it. Governments may be better informed on the importance of climate change mitigation than others for various reasons. They may have reliable information from domestic research institutions or it may be relatively high on the political agenda. The results in Potters et al. (2005) confirm that a leadership action of a well-informed player is indeed understood as predicted by theory. Followers are able to interpret a signal, even if the information is still not complete. A skeptical government may thus be convinced of the importance of mitigation once it observes other putting sizable efforts into it.

Since the interaction is repeated, an effect of reputation building by the leader as in Hermalin (2007) would be possible. For this the leader would have to maintain his mitigation efforts consistently.

The "quality of the public good" described in Andreoni (2006) in the case of climate change would be its importance, that is the utility from a future when mitigation is implemented versus the utility from a future without mitigation. This difference can take on any value in principle. The effect described in Andreoni (2006) could therefore occur: Follower nations could suspect that a leader nation sends the signal corresponding to a high importance of mitigation even though it is only moderately important. The reason for this deception would be to lure the followers into vigorous abatement even though they wouldn't do it if they were fully informed. To signal a high value of climate change, the leader would thus have to send a very convincing signal in the form of extreme mitigation with his own policy area.

Potters et al. (2005) provides some reassurance on how well a climate mitigation signal of the leader would be understood. Subjects seem to be well versed in understanding public good signals, even if it only reduces uncertainty and does not eliminate it. Governments can thus be expected to understand them all the more.

4 Research and Development by the Leader

Sections 2 and 3 have in common that the focus is on cooperation. In both cases it is assumed that there is the possibility to invest in a given public good and that in general it is provided inefficiently. Leadership could improve cooperation through coordination.

This section is concerned with the possibility for a leader to gain and share knowledge that will facilitate the implementation of the public good. The leader can provide a service

to the other players by taking the lead. This knowledge provision can take three different forms. In Section 4.1 I consider policy. It may be unknown which policy is most effective in providing the public good. In Section 4.2, I consider the technology which is developed by the leader in response to the policy and which may allow followers to adapt very quickly to environmental policy. Section 4.3 looks at the information on the cost of achieving noticeable progress on the environmental objective.

The form of leadership explored in this section falls into the category of leading by example as the previous sections, since the knowledge acquired and shared by the leader can only be acquired by implementing climate change mitigation. In contrast to the Porter hypothesis, the kind of effect of leadership action described here will only be beneficial to the leader when others follow. Even though the leader gains knowledge by leading, the cost of mitigation will only be balanced by the benefits of less dramatic climate change if others mitigate as well.

4.1 Policy Diffusion

The papers discussed in this section show that diffusion of policies, in particular successful ones, can be observed on all levels of government and for different types of policies. Shipan and Volden (2008) investigates the interaction of cities, Volden (2006) uses US states and Holzinger et al. (2008) as well as Gilardi (2010) find evidence of diffusion among industrialised countries. While the broad range of policies investigated shows that the pattern is quite general, Holzinger et al. (2008) is particularly informative in the context of climate policy since it concerns environmental policy.

The process of policy diffusion is investigated intensively in political science. Using one specific policy in US states, Volden (2006) finds that successful policies are copied by other states more often than failing policies. Following up on this with a paper on policy diffusion between US cities over 25 years, Shipan and Volden (2008) finds that cities learn policies from early adopters. In addition, it turns out that larger cities drive the process of policy innovation and that smaller ones are more likely to follow.

Holzinger et al. (2008) investigates international convergence in environmental policy. In an empirical study of 24 industrialized countries between 1970 and 2000 they find strong convergence. Looking at the mechanisms behind the convergence, they find that this development is caused mainly by international harmonization and transnational communication.

Investigating policy diffusion for unemployment benefits retrenchment among OECD na-

tions, Gilardi (2010) finds evidence that countries learn selectively from others. The learning is selective in the sense that it differs by the political camp (right or left) of the government in place.

Kruger et al. (2007) describe how policy diffusion works in the context of climate policy using the example of the EU Emissions Trading Scheme. It is itself largely inspired by the US sulfur dioxide trading system and now serves as a rich source of insights for future trading systems and potentially a global trading system.

4.2 Technology

Eaton and Kortum (1999) find international technology diffusion to be quite powerful as foreign innovations are two thirds as effective as domestic innovations. They conclude from this that the US and Japan drive growth in other countries to a large extent. Acemoglu and Zilibotti (2001) confirm just how powerful this transfer of technologies is. The least developed countries adopt technologies developed in OECD countries thus creating a mismatch between the foreign technology and the domestic skills. Keller (2004) stresses the importance of technology diffusion even more forcefully. For some countries 90 percent of domestic productivity growth originates from foreign-developed technology. The G-7 countries account for the creation of almost all of the new technology. Benhabib and Spiegel (2005) give a long list of references on empirical measurements of technology spillover and proposes a theory on how technology is adopted from abroad which is capable of explaining why there is no fast convergence in spite of technology diffusion.

In recent years the general observation of technology diffusion has been investigated for the case of "green" technology. Popp (2006) shows that technology development responds to domestic environmental regulatory pressure and that these then become an important building block abroad when similar regulation is introduced there. Technology transfer has played a very important role for the emergence of wind turbine manufacturers in India and China, see Lewis (2007), Zhang et al. (2009) and Wang (2010), as well as the very advanced photovoltaic technology in China, see De La Tour et al. (2011).

4.3 Cost

The costs involved in introducing new regulation are often difficult to estimate. Harrington et al. (2000) show that in the majority of cases, ex ante estimates are too high by comparing

cost estimates before a policy is implemented with assessments of actual costs afterwards. A major source for errors in cost estimates are technological innovations which were not anticipated at the time the regulation was introduced.

Brandt (2004) provides a model where abatement costs are uncertain but correlated. By unilaterally engaging in abatement, a country can signal the costs to other countries. One country becomes privately informed about the abatement costs and takes the lead following this additional information.

Elofsson (2007) uses a similar model with uncertainty over abatement cost. In this case, there are two risk-averse countries with uncertain, but correlated costs of abatement. The level of uncertainty differs so that the countries with low uncertainty is the natural candidate for taking unilateral action.

4.4 Relevance for Climate Change Mitigation Policy

Climate change mitigation requires the development of suitable policy, it will be facilitated by an adaptation of technology and estimates of policy costs are uncertain. In all three domains therefore, a leader could acquire knowledge which would improve the cost benefit ratio for potential followers and might move them across a threshold for participation.

Several policy options are considered to implement climate mitigation and each option allows for countless variants. Followers are likely to participate in the learning process of the leader and could copy a successful system much in the way that Volden (2006) has demonstrated countries to be capable of doing. Kruger et al. (2007) and Ellerman and Buchner (2007) show that the European Union Emission Trading Scheme serves as a policy laboratory for the entire world. A leader could exploit the convergence progress described by Holzinger et al. (2008) by introducing a desirable policy with the aim of foreign policies to converge towards it.

Popp et al. (2010) have shown that a country taking the lead in climate policy will adapt to this policy. Firms will adjust their production and research to align with the changed set of incentives. Eaton and Kortum (1999) in general and De La Tour et al. (2011) in particular have shown that technology diffuses to other regions once one country or region has developed low-carbon technology. For countries contemplating the option of following a leader in setting rigorous environmental policy, the availability of the corresponding technology might make the difference. The follower will not have to develop the technology needed under this policy

itself. He could catch up and make rapid progress in making its production sustainable thus reducing the cost of the change.

Finally we have seen theoretical models in Brandt (2004) and Elofsson (2007) that the leader would also likely provide more accurate information on implementing climate change mitigation. Harrington et al. (2000) have shown that underestimating technological adaptation is one cause for overestimating policy cost so that the development of technology and the increased precision of policy costs could interact to let potential followers make a downward correction of their own cost estimates.

5 Political Dynamics

As international climate negotiations continue to fail, alternative approaches are discussed increasingly under the aspect of political feasibility. Urpelainen (2013) classifies this politics-minded literature into improved treaty design, bottom-up approaches and dynamic climate governance. This literature does not treat the role of leadership explicitly, but the second and third of these categories contain an element of leadership. As opposed to the economic mechanisms considered so far, the literature is concerned with the details of political dynamics and thus offers additional insights on the potential for leadership.

To structure the understanding of the debate on the politics of climate change, we continue to view climate mitigation as a public good to which countries could contribute cooperatively (through a treaty), simultaneously (through uncoordinated small contributions) or with the intention to lead (through large unilateral contributions). The objective will be to identify which political mechanisms may allow for a leadership contribution to increase contributions by others.

Much space in the debate is dedicated to explaining why bottom-up approaches, that is small and uncoordinated contributions, are more likely to be successful than a global treaty. A major argument is that small initiatives are more flexible since they can be fine-tuned to regional needs and can be adjusted over time (Urpelainen, 2013). Ostrom (2014) points out that communication and monitoring is easier in regional agreements. Peters and Hertwich (2008) add that negotiations within an established regional dialogue means fewer political obstacles and thus provides a practical base for climate policy. Victor et al. (2005) points out that local agreements provide the opportunity to bundle climate policy with meeting regional needs such as reducing local air pollution.

From these arguments, however, it is not clear how the bottom-up approach could produce leadership effects. The political literature does identify three mechanisms that might provide a leadership effect. The remainder of the section will take a closer look at them.

5.1 Development of Technology

The first effect is that technology developed in response to regional climate policy will facilitate the technological adaptation of other regions and thus increase their probability to participate. This is the effect described for the economic literature in Section 4.2.

Urpelainen (2013) defines an individual contribution (called a "small win") as having *transformation potential* when it affects the payoff for other potential contributors. This concept is closely related to what we understand as leadership here, in particular in the form of Section 4. A major source for transformation potential are technological advances which improve the cost benefit ratio of climate policy. This is based on the realization that the indirect effect of spurring innovation is a major aspect of incentives to reduce emissions. Barrett (2009) points out that stabilizing carbon dioxide concentrations can only be achieved by rapidly developing new technology, so that any nation contributing to their development is providing an urgently needed service to all. Similarly, Fischer and Newell (2008) emphasize the central role of technology in realizing gains in emission reductions.

5.2 Policy Expertise

The second effect is the sharing of experience with climate mitigation policy. When an individual country experiments with a new policy tool, others can adopt it selectively based on success and specific suitability. This type of leadership effect was described in Section 4.1.

The literature on the politics of climate policy recognizes the importance of policy experimentation. Elinor Ostrom favors a polycentric approach which allows "experimentation and learning from experience with diverse policies" (Ostrom, 2010). It is inspired by the research on providing other public goods, such as public safety, where it proved quite successful (Ostrom, 2014). Fisher and Costanza (2005) show that in the case of individual US states this process of experimenting and learning policies already "helped to identify easy and inexpensive routes to emission reductions". Lutsey and Sperling (2008) add another aspect: Small scale policy implementation allows testing the political response to new policy tools. Knowing that a policy was accepted in a small policy area will make politicians in larger

units more confident to use them as well.

5.3 Political Crystallization

In addition to the previous effects, the literature on the politics of climate mitigation has also identified a genuinely political effect of leadership. David Victor and coauthors seem to have a process akin to crystallization in mind. A seed crystal of a few emission heavyweights could agree on effective climate mitigation policy and implement it. The reduced number of leading participants could agree more easily than a climate summit representing all nations. Other nations would then join the initiative until full participation is reached.

In Martin (2005) the Canadian Prime Minister Paul Martin proposed the foundation of a "L20" group of world leaders to work on political problems following the role the G20 played for economic problems. Victor et al. (2005) takes up this idea and adapts it to climate policy. Since the L20 could negotiate more effectively than a large climate summit, it could establish a comprehensive and functioning treaty. Since a large share of the world's emissions are covered by only a few countries, it could implement meaningful emission reductions. Such an approach has worked on controlling acid rain and water pollution and a few other international agreements.

Victor (2006) details the idea further, based on the "k group" theory developed in political science by Hardin (1982), Snidal (1985) and Schelling (2006). This concept describes the minimum number of participants necessary to make participation rational. The group should not be too large since this would make negotiations increasingly complex. It should not be too small since this would cover too little of total emissions. Victor (2006) suggests that the optimum could be the twelve largest emitters. A successful example for such an approach is the World Trade Organization, which started the General Agreement on Tariffs and Trade (GATT) with a small number of countries and then widened and deepened cooperation.

An initiative of a group of large emitters could also fulfill on a larger scale the role which US states have nationally. According to Fisher and Costanza (2005), the policy of the US states "acknowledges the need for climate-change policies and for setting targets", a function of signaling described in Section 3.

A group of important emitters could thus take the lead on climate policy with the intention of providing the crystal seed without which conditional cooperators among other nations would not take any action at all. Like countries joining the GATT or the EU, these conditional

cooperators might be willing to join a functioning system of proven cooperators. The sacrifice of leading by example may be the crucial factor of success compared to the verbal pledges in climate negotiations.

6 Conclusion

This paper has collected three economic plus one political categories of possible mechanisms which could trigger a positive reaction from followers once a country or region has taken the lead on climate policy. A leader's unilateral introduction of significant climate change mitigation could elicit the introduction of similar policies elsewhere out of a desire to contribute a fair share to the global public good. It might signal crucially needed information on the preference for a minimization of climate change and the value of this public good. It could provide a valuable service in the form of knowledge which makes it more a attractive to followers. From the political point of view it could supply an expandable platform of cooperation.

Two caveats apply. Some of the mechanisms shown here have been demonstrated to exist for individuals in a lab setting. These will not be transferable without modifications to strategically interacting nations. Second, there is very little evidence on size of the described effects. A potential leader will thus very probably not be able to assess quantitatively how other nations will react. However, both of these caveats also apply to some extent to the negative reaction in the form of free riding.

Any prediction on the reaction of nations or governments to an unprecedented event, such as decisive climate leadership, necessarily has a speculative aspect. This is true for possible positive, but also for negative reactions. Both have a theoretical and an experimental basis and depend on assumptions or the exact setup. In a way, this paper provides an optimistic counterbalance to the prevailing pessimistic assessment of unilateral climate action.

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