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# International environmental agreements with consistent conjectures

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ABSTRACT

We introduce consistent conjectures into Barrett (1994) canonical model of international environmental agreements. The existing literature assumes inconsistent Nash conjectures, despite the fact that policymakers recognize that abatement levels are strategic substitutes and increases in abatement generate carbon leakage. With consistent conjectures much of the conventional wisdom is reversed. The non-cooperative abatement level is below the Nash equilibrium. The difference between Nash and consistent conjectures is greatest when benefits are large and costs are small. We find that large coalitions cannot form. However, small coalitions can result in substantial increases in abatement relative to the non-cooperative outcome.



## Introduction

The current debate on International Environmental Agreements (IEAs) to reduce greenhouse gas emissions is dominated by the recognition of offsetting behavior. The fundamental issue is carbon leakage, which means that an increase in abatement by IEA signatories is met by a reduction in non-signatory abatement. Barrett (1994) is the seminal paper responsible for much of the conventional wisdom regarding IEAs. Barrett (1994), and all of the existing IEA literature, adopts Nash conjectures where each nation assumes that there is no response by other nations to changes in own abatement.

The Nash conjecture is a particularly bad assumption for nations' greenhouse gas emissions, as the entire concept of carbon leakage is an acknowledgement that other nations do respond. There is a large body of empirical literature on the effects of carbon leakage (for example Babiker, 2005; Elliott et al., 2010), yet the theoretical literature lags behind. No previous IEA has considered non-Nash conjectures and the resulting strategic implications of carbon leakage (see Finus, 2003 for a survey). This paper introduces conjectural variations to Barrett's model and builds an IEA that fits with the reality of carbon leakage as understood by actual policymakers.

While discussing the Kyoto Protocol in 1997 Senator Charles Hagel told the United States Senate the following (Kuik and Gerlagh, 2003). “The main effect of the assumed policy would be to redistribute output, employment and emissions from participating to non-participating countries.” Clearly, Senator Hagel anticipated carbon leakage and recognized that

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abatement levels are strategic substitutes. Subsequently, on July 25, 1997 the US Senate voted 95–0 in favor of the Byrd–Hagel resolution which stated that "The United States should not be a signatory to any protocol to, or other agreement regarding, the United Nations Framework Convention on Climate Change of 1992…"

More recently in September 2009 OECD Secretary General Gurria told the Informal Ministerial Meeting on Climate Change "If the EU were to cut emissions by 50% by 2050, with no other countries taking any action, our analysis suggests that almost 12% of their emissions reductions will be "leaked," or offset, through increased emissions in other countries."[1] This awareness also extends to the popular press and is part of the current public debate. In May 2014 Washington Post columnist Samuelson (2014) wrote "… any further U.S. emissions cuts would probably be offset by gains in China and elsewhere." Policymakers, negotiators and commentators are explicit in their non-Nash conjectures, however the existing IEA literature has adamantly retained a Nash conjecture of zero response.

This type of non-Nash behavior is called a conjectural variation in the oligopoly literature. With conjectural variations any change in own quantity is anticipated to induce a response by others (Bowley, 1924). Bresnahan (1981) extended this idea and proposed a consistent conjecture equilibrium (CCE). In a CCE the conjecture is assumed to be correct and equal the actual best-response slope.

The logical inconsistency of Nash conjectures is exacerbated when signatories to an IEA form coalitions. The IEA literature uses the concept of internal and external stability from D'Aspremont et al. (1983) for participation decisions, together with the assumption of Nash conjectures for abatement decisions. Internal stability means that no signatory would earn a higher payoff by leaving and external stability means that no non-signatory would earn a higher payoff by joining the agreement. A coalition of signatories is stable when it is both internally and externally stable. However, internal stability is itself by its very nature a non-Nash conjecture. Each nation compares their payoff as a coalition member with the potential payoff if they were to individually leave the coalition.

When a member considers leaving a coalition and reducing abatement it "correctly" anticipates (i) how the remaining signatories will reduce their abatement, (ii) how the other non-signatories will increase their abatement and (iii) how the nation that is leaving will best-respond to these changes. However, these "correctly" anticipated responses are determined by reaction functions that are derived from an inconsistent Nash conjecture. Thus, nations recognize the existence of carbon leakage when choosing to participate in an IEA, but do not recognize carbon leakage when choosing abatement levels.

Stackelberg models allow for a conjectural variation, and with a single follower the leader's conjecture is consistent and equal to the follower's best-response slope. When there are two or more followers the Stackelberg equilibrium with Nash conjectures is inconsistent since the conjecture determines the follower's aggregate best-response function. To the best of our knowledge, we are the first to explore this point. Barrett (1994) assumes that signatories to an IEA behave as a Stackelberg leader and collectively choose their most desired location on the aggregate best-response function of the followers. In Barrett (1994) the aggregate follower reaction function is obtained from Nash conjectures. Stackelberg leadership with more than one follower and Nash conjectures is itself an inconsistent equilibrium.

The use of consistent conjectures has been criticized as imposing an inherently dynamic process where players learn the best-response slopes of their rivals (Friedman, 1983, pp. 109–110). However, consistent conjectures have been applied to many situations where Nash conjectures are hard to justify. Consistent conjectures have been used in models of public goods (Cornes and Sandler, 1985), international trade (Fung, 1989), estimates of market power (Perloff et al., 2007), and strategic incentives in teams (Heywood and McGinty, 2012). In all of these areas player's recognize that their rivals' choice variables are either strategic substitutes or complements and do anticipate a response by others.

McGinty (2014) justifies the use of consistent conjectures in a two-nation version of Barrett (1994) model and provides the rationale for our approach. That paper shows that consistent conjectures emerge from individual payoff maximization in addition to the traditional approach of imposing consistency by assuming that conjectures match the actual best-response slope (Bresnahan, 1981; Kamien and Schwartz, 1983). There is a payoff advantage to recognizing offsetting behavior and that abatement levels are strategic substitutes. The CCE emerges as the unique subgame perfect equilibrium of a game where beliefs are chosen before abatement levels, as with actual policymakers. That paper shows that abatement is lower at the CCE than the Nash equilibrium (NE), a result first obtained for public goods by Sugden (1985). There is an individual payoff advantage to having a consistent conjecture, however both players are worse off at the CCE. Thus, there is a Prisoner's Dilemma in conjectures since the consistent conjecture dominates a Nash conjecture. The NE is not the appropriate non-cooperative outcome when policymakers have conjectures that differ from Nash. This paper shows how the difference in the non-cooperative outcome effects abatement and coalition stability in a model with $n$-nations.

The IEA is modeled as a three-stage game following Barrett (1994). In the first stage nations decide to participate in the agreement or not. In the second stage IEA signatories collectively choose abatement to maximize their combined payoff. In the third stage non-signatories individually chose abatement after observing signatory abatement. Barrett's central conclusion is that there is an inverse relationship between the gains to cooperation and the number of signatories to an IEA. Barrett finds that an IEA with full participation is possible, but only when there is essentially no difference between the Nash equilibrium of no cooperation and the social optimum of full participation.[2] This occurs when the benefits from abatement are large and the costs are low. However, this is precisely when the difference between the CCE and the NE is the largest.

[1] The full text is available at: http://www.oecd.org.reducinggreenhousgasemissionsindevelopedcountries.htm.

[2] Finus (2003) survey of the self-enforcing IEA literature indicates that large coalitions are only possible with both Stackelberg leadership and concave benefits.