Self-Regulation, Negotiated Agreements and Social Welfare

Thomas P. Lyon* and John W. Maxwell†

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Abstract

The literature on voluntary agreements studies self-regulation, negotiated agreements and public voluntary programs, typically in the shadow of a legislative threat. Prior studies have examined each of these instruments in isolation, but interactions between them have received less attention. We show that in the presence of multiple voluntary instruments, equilibrium outcomes and welfare results depend critically on the timing of moves and the bargaining power of each player. In contrast to prior work, we find conditions under which a full-information equilibrium involves self-regulation and no negotiated agreement. We also show that the opportunity to sign a negotiated agreement only reduces welfare when the regulator has little bargaining power and the firm can commit to an inefficient threat to eschew self-regulation should negotiations fail. More generally, we stress the need for the literature to take account of the "technological detail" of particular contexts when studying voluntary agreements.

1 Introduction

One of the most striking changes in environmental policy since the 1990s has been the substitution of voluntary programs for mandatory government regulation. Industry self-regulation, negotiated agreements, and public voluntary programs all have become more prominent as command-and-control regulation, and even market-based instruments, have

*Dow Chair of Sustainable Science, Technology and Commerce, Ross School of Business, University of Michigan, Ann Arbor, MI, 48109. Email: tplyon@umich.edu.

†W. George Pinnell Professor, Kelley School of Business, Indiana University, Bloomington, IN, 47405. Email: jwmax@indiana.edu.

attracted less interest. (Lyon and Maxwell 2004) The literature has made considerable progress in understanding these voluntary approaches taken individually. There are theoretical papers addressing self-regulation (Maxwell, Lyon and Hackett 2000; Maxwell and Decker 2006; Denicolo 2008), negotiated agreements (Miceli and Segerson 1998; Manzini and Mariotti 2003; Glachant 2005; Glachant 2007; Dawson and Segerson 2008), and public voluntary programs (Cararro and Siniscalco 1996; Wu and Babcock 1999). There is also a sizable empirical literature evaluating the performance of voluntary agreements.[1]

There has been much less work exploring how mutiple voluntary instruments interact with one another. This is an important deficiency, since whenever governments get involved in negotiated agreements or public voluntary programs, firms retain the ability to engage in self-regulation. Lyon and Maxwell (2003) show that the possibility of a public voluntary program may undermine a firm's incentives to undertake self-regulation. Similarly, Fleckinger and Glachant (2011) show that the possibility of a negotiated agreement can undermine a firm's incentives for self-regulation. Although the two papers differ in the timing of moves, in both cases welfare might increase if the government were prohibited from using a voluntary agreement. Thus, it is important to understand clearly the specific conditions under which voluntary agreements can be expected to perform well when self-regulation is taken into account.

In the present paper we focus on the robustness of insights from models that combine self-regulation and negotiated agreements, emphasizing issues regarding the sequence of moves, and the bargaining power of each player.[2] In doing so, we generate sharper predictions regarding when negotiated agreements will be used, and when they are likely to be welfare-enhancing. One contribution of the paper is that we identify situations in which the fully-informed regulator may endogenously refuse to sign a voluntary agreement. The previous literature predicts that when the regulator has full information, a voluntary agreement is always signed when it is an available policy tool.[3] Since we observe many situations in which regulators opt not to sign voluntary agreements, it is important to understand when such decisions are optimal. A second contribution is that we find that the only conditions under

[1] For overviews of the literature on voluntary agreements, including empirical findings, see Alberini and Segerson (2002), Baranzini and Thalmann (2003), OECD (2005), Morgenstern and Pizer (2007), Lyon and Maxwell (2004, 2007), Khanna and Brouhle (2009), and Blackman (2010).

[2] We leave a similar study of how the sequence of moves affects the interaction between self-regulation and public voluntary programs for future work.

[3] Glachant (2007) studies a case where the regulator has incomplete information regarding the firm's discount factor, and finds that a VA is not always signed in this setting.

which the opportunity to sign a negotiated agreement is welfare-reducing are when (a) the regulator's bargaining power is weak, and (b) the firm can credibly commit to an inefficient threat to eschew self-regulation should negotiations with the regulator break down. Because such a commitment is not a dynamically consistent strategy for the firm, however, its use is not robust to changes in the sequence of moves.

A general contribution of the paper is to emphasize linkages between the literature on voluntary agreements and the literature on incomplete contracts. The timing issues that we emphasize here serve as a reminder that the VA literature remains quite young, and is not fully developed. There are many parallels between the design of voluntary agreements and the design of contracts more generally, yet the VA literature has yet to incorporate many of the insights from the extensive literature on the economics of contracts. For example, Bolton and Dewatripont (2005) include in their textbook on contract theory substantial sections on models of incomplete information, on disclosure of private certifiable information, and on incomplete contracting with unverifiable information. These topics have received almost no attention in the VA literature to date.[4] Within the incomplete contracting literature—and most real-world contracts are incomplete—the issues of investment, hold-up, and renegotiation design are crucial yet they also have not been reflected in theoretical work on voluntary agreements. This list of topics is clearly far beyond the scope of the present paper. Here we focus on issues of timing in the negotiation process, bargaining power and commitment. These issues have been at the heart of papers studying the design of contracts, dating back at least to the seminal work of Hart and Moore (1988), and they continue to be active areas of current work as represented by the recent papers of Lyon and Rasmusen (2004), Wickelgren (2006), Watson (2007), Evans (2008), and Hoppe and Schmitz (2011).

The remainder of the paper is organized as follows. Section 2 considers a model in which the firm can engage in self-regulation prior to the negotiation of a VA. Section 3 reverses this order and allows the firm to self-regulate in the event that VA negotiations break down. Section 4 considers a case where self-regulation and the negotiation of a VA occur simultaneously. Section 5 discusses the policy implications of our analysis, and considers the endogenous timing that results if the players can choose when the stages of the model occur. Section 6 presents a numerical example that illustrates our main points, and offers some intuition regarding the magnitude of the differences in outcomes across different models. Section 7 offers conclusions regarding how to model negotiated agreements, what

[4]The one exception is Glachant (2007), which allows for asymmetric information regarding the firm's discount rate and assuming voluntary agreements are non-binding.

can be expected of them empirically, and important directions for further work.

2 A Model of Self-Regulation and VAs

There are two players in our model, a regulator (she) and a firm (he), operating against the background threat of legislation. The firm emits pollution, and can invest in a quantity of abatement q; he desires to minimize his cost of abatement $C(q)$ where $C(0) = 0$, $C'(q) \geq 0$ with $C'(0) = 0$, and $C''(q) > 0$. Net social welfare of abatement is given by $U(q)$, with $U'(q) > 0$ and $U''(q) < 0$ for all $q \geq 0$, which is maximized at a level Q such that $U'(Q) = 0$. There is a background threat that legislation will impose an emissions quota of Q, which occurs with probability p, where p depends upon the amount of effort the regulator expends to pass the bill.[5] The regulator's objective is to maximize $\overline{U}(Q) - \gamma(p) \equiv pU(Q) + (1 - p)U(r) - \gamma(p)$, where r is the amount of self-regulation done by the firm (which may be zero) and $\gamma(p)$ is the regulator's cost of pressing for legislation that would mandate Q with probability p. We assume $\gamma(0) = 0, \gamma'(p) \geq 0$ with $\gamma'(0) = 0$, and $\gamma''(p) > 0$, which together ensure that legislation does not pass unless the regulator expends some effort, and that the analysis focuses on interior solutions.[6] For technical reasons that will become apparent below, we also assume $\gamma'''(p) \leq 0$. As an alternative to legislation, the firm and the regulator can negotiate a voluntary agreement (VA) requiring the firm to invest in an abatement level q^{VA}, in which case legislation is taken off the table.

Throughout most of the paper, we treat the firm's self-regulatory choice as making a credible commitment to undertake the investment r, by making a public declaration that puts the firm's reputation at stake or signing a contract with a third-party that makes it costly for the firm to renege on the investment promise. This avoids the complicating issues of timing that arise if the firm must make a physical investment to demonstrate the credibility of its commitment to take action, rather than simply signing a contract.[7] As an example

[5] The model can be extended to allow the firm to influence the probability that the quota is approved, but this does not change the qualitative nature of the results.

[6] The implicit assumption here is that the political effort involved in passing legislation is independent of the legislation's stringency. We adopt this simplifying assumption in order to facilitate comparison with Fleckinger and Glachant, especially since this is the assumption under which they find welfare-reducing effects from self-regulation.

[7] Wickelgren (2006) illustrates the complications that arise when timing of investment is a key feature of the model. Glachant (2007) presents a model in which the firm's investment under a negotiated agreement cannot be observed for some number of periods. We assume investment commitments are observable

of self-regulation through contract, consider the 2007 buyout of of TXU, a Texas utility company, by private equity firm Kohlberg Kravis and Roberts. (Sorkin 2007) The parties invited the Environmental Defense Fund (EDF) to participate in the negotiations, which led TXU to commit to reduce its planned coal plants from 11 to 3. The arrangement attracted a large amount of media attention, and even if the agreement were not legally enforceable it would be difficult for TXU to walk away from it without sizable harm to its reputation. We discuss how our model would be changed in a more complex model of investment timing in section 5.

We adopt a simple model of the bargaining process, letting one player or the other make a take-it-or-leave-it (TIOLI) offer. This creates two extreme possibilities, with one player or the other having all the bargaining power. Less extreme allocations of bargaining power can be created by allowing each player to make a TIOLI offer with a given probability $\alpha \in (0, 1)$. Our formulation has the advantage of allowing us to discuss the impact of bargaining power in a very streamlined fashion.

The sequence of moves in our initial model is as follows:

1. The firm unilaterally makes an investment that commits him to abate a quantity of pollution $r \geq 0$.

2. The player with the bargaining power makes an offer of an abatement level $q^{VA} \geq r$.

3. The respondent accepts or rejects the offer. If an agreement is reached, the firm complies with the agreement and the game ends.

4. If an agreement is not reached, legislation is considered, and passes with probability p, in which case the firm complies. Otherwise the abatement level remains r.

For simplicity, discounting is not incorporated in the model, as it would complicate notation substantially without changing the basic issues we emphasize. We solve the game through backwards induction, seeking subgame-perfect equilibria.[8]

immediately in order to focus more sharply on the sequence of moves.

[8] The structure of the model in this section is similar to that of Fleckinger and Glachant (2011), but employs a rather different model of the bargaining process. Nevertheless our structure allows us to capture the key implications of their model.

2.1 Stage 4

If there is no negotiated agreement, then legislation to impose the optimal quota Q is considered. In choosing how much effort to devote to passage of the quota, the regulator's problem is to

$$\max_p pU(Q) + (1-p)U(r) - \gamma(p), \tag{1}$$

which has first-order condition

$$U(Q) - U(r) = \gamma'(p). \tag{2}$$

This condition implicitly defines the function $p(r)$, which represents the regulator's optimal probability of legislation given the firm's abatement level r. It is easy to see from (2) that as long as the level of self-regulation chosen by the firm is less than Q, then the regulator will find it optimal to expend a positive level of effort to support legislation mandating the quota. Totally differentiating (2) yields $p'(r) = -U'(r)/\gamma''(p) < 0$, even at $r = 0$.[9] Thus, self-regulation has a preemptive effect in the sense that it reduces the likelihood of legislation, but does so at a declining rate. At the same time, it is easy to see that it will never be optimal for the firm to self-regulate to the level Q, since there is no guarantee legislation will pass, and higher abatement is more costly for the firm.

2.2 Stage 3

At this stage, the player without bargaining power chooses whether to accept or reject the other player's offer. The firm will accept a VA at an abatement level q if

$$C(q) \leq \overline{C}(r) \equiv p(r)C(Q) + (1-p(r))C(r). \tag{3}$$

The regulator will accept a VA at an abatement level q if

$$U(q) \geq \overline{U}(r) \equiv p(r)U(Q) + (1-p(r))U(r) - \gamma(p(r)). \tag{4}$$

2.3 Stage 2

At this stage, the player with the bargaining power decides what to offer the other player. We define $q^R(r)$ to be the offer made by the regulator when voluntary abatement level r is

[9] In addition, $\gamma''' \leq 0$ is sufficient to ensure $p''(r) = [-\gamma''(p(r))U''(r) + U'(r)\gamma'''(p(r))p'(r)]/[\gamma''(p(r))]^2 \leq 0$.

chosen by the firm, and $q^F(r)$ to be the offer made by the firm when its voluntary abatement level is r. We consider each of these possibilities in turn.

Regulator Makes the Offer. If the regulator has the bargaining power, then she makes an offer q^R that makes the firm just indifferent between signing the VA and entering the legislative contest, so that equation (3) holds with equality.

Firm Makes the Offer. If the firm has the bargaining power, then he makes an offer q^F that leaves the regulator just indifferent between signing the VA and entering the legislative contest, so equation (4) holds with equality.

Our first proposition characterizes the outcome of stage 2.

Proposition 1 *Regardless of the allocation of bargaining power, a VA is always signed. For any r, $q^R(r) > q^F(r)$.*

Proof. Because $C(q)$ is convex, Jensen's Inequality implies that $C(p(r)Q + (1 - p(r))r) < p(r)C(Q) + (1 - p(r))C(r)$. Since $C(q)$ is increasing in q, from (3) the regulator will demand $q^R > p(r)Q + (1 - p(r))r$ and the firm will accept the offer. Similarly, Jensen's Inequality implies that $U(p(r)Q + (1 - p(r))r) > p(r)U(Q) + (1 - p(r))U(r) - \gamma(p(r))$. For the firm, the relevant range of offers is $q^F < Q$, since the firm will never be forced to do more than Q. On the relevant range, $U(q^F)$ is increasing, so from (4) the firm will offer $q^F < p(r)Q + (1 - p(r))r$ and the regulator will accept the offer. ■

Proposition 1 establishes that the voluntary agreement will always be signed, and that its stringency depends upon the allocation of bargaining power. If the regulator has the bargaining power, she extracts the available surplus while still ensuring that the firm will be willing to sign a VA at $q^R(r)$. If the firm has the bargaining power, he extracts the available surplus, while still ensuring that the regulator is willing to sign a VA at $q^F(r) < q^R(r)$.

2.4 Stage 1

At the first stage of the game, the firm chooses how much voluntary abatement to undertake, anticipating the play of the remainder of the game.

Regulator Makes the Offer. In this case, the outcome of Stages 2 and 3 is that the parties sign a VA at $q^R(r)$, determined by (**??**). Since the firm's costs are increasing in q^R, the firm chooses r to minimize $C(q^R) = \overline{C}(r)$. Thus, the firm's problem has first-order condition

$$\frac{\partial \overline{C}(r)}{\partial r} = p'(r)[C(Q) - C(r)] + (1 - p(r))C'(r) = 0.$$

We will denote the solution to this expression by $r^* = R > 0$.[10] Note that $C(q^R(R)) = \overline{C}(R) = p(R)C(Q) + (1 - p(R))C(R) > C(R)$, so $q^R(R) > R$. Thus, when the regulator has the bargaining power, the VA she negotiates results in more abatement than the firm would undertake via self-regulation.

Firm Makes the Offer. In this case, the outcome of Stages 2 and 3 is that the parties sign a VA at $q^F(r)$ determined by (4) holding with equality. Since the firm's costs are increasing in q^F, the firm chooses r to minimize q^F. Totally differentiating (**??**) we obtain

$$U'(q^F)dq^F = p'(r)U(Q)dr - p'(r)U(r)dr + (1 - p(r))U'(r)dr - \gamma'(p(r))p'(r)dr$$

Thus,

$$\frac{dq^F}{dr} = \frac{p'(r)[U(Q) - U(r) - \gamma'(p(r))] + (1 - p(r))U'(r)}{U'(q^F)}.$$

The denominator is positive. Recall that at Stage 4, the regulator's optimal choice of γ is determined by (2), so that $U(Q) - U(r) = \gamma'(p)$. Hence, the numerator reduces to $(1 - p(r))U'(r) > 0$. Thus, $dq^F/dr > 0$, and the firm undertakes no voluntary abatement in stage 1.

The foregoing discussion implies the following result.

Proposition 2 *In Model 1, if the regulator has the bargaining power, the firm chooses $r^* = R > 0$, and a VA is signed at $q^R(R) > R$. If the firm has the bargaining power, he chooses $r = 0$, and a VA is signed at $q^F(0)$.*

Let us summarize the discussion of this section. If the regulator makes the offer, then the firm chooses r strategically to weaken the legislative threat facing it should VA negotiations break down. If the firm makes the offer in the VA negotiations, then the firm commits to $r = 0$, and uses his bargaining power to capture all the surplus from the negotiation, obtaining a VA at $q^F(0) < q^F(R) < q^R(R)$.

An intuitive understanding of the firm's self-regulatory strategy when he has the bargaining power merits further explanation. The simplest way to understand the result is to note that $\overline{U}(r)$ is increasing in r, and that a higher level of $\overline{U}(r)$ requires the firm to offer a stronger VA. Hence, the firm chooses $r = 0$. More subtly, we note that the surplus created by signing the VA consists of two parts: (a) elimination of the transaction costs $\gamma(p(r))$ that would be expended by the regulator if she enters the legislative contest, and (b) reduction

[10] Our technical assumption that $\gamma'''(p) \leq 0$ is sufficient to ensure the second-order condition holds. Since $p'(0) < 0$ and $C'(0) = 0$, we know that $R > 0$.

of risk for both of the parties. Because the objective function maximized by the regulator is concave and the objective function minimized by the firm is convex, both parties are risk averse, and prefer to avoid the uncertainty associated with the legislative contest. Note that the transaction costs $\gamma(p(r))$ are decreasing in r, since $\gamma'(p) > 0$ and $p'(r) < 0$. Note also that the risk to which the parties are exposed is decreasing in r. Thus, the surplus created by the VA is decreasing in r. When the regulator captures all the surplus from the VA, the firm has no stake in maximizing the surplus, and instead focuses on minimizing his own expected costs. To do so, he invests in a strictly positive level of r, which has the additional effect of decreasing the surplus created by the VA. When the firm captures all the surplus, however, he refuses to self-regulate, maximizing the surplus created by the VA and then capturing it all for himself.

3 A Model of VAs and Self-Regulation

In this section we reverse the sequence of negotiation and self-regulation, but the final stage remains the legislative contest. Thus the sequence of moves is as follows:

1. The player with the bargaining power makes an offer of an abatement level q^{VA}.
2. The respondent accepts or rejects the offer. If an agreement is reached, the firm complies with the agreement and the game ends.
3. If negotiations break down, then the firm unilaterally makes an investment that commits him to abate a quantity of pollution $r \geq 0$.
4. After the firm invests in self-regulation, legislation is considered, and passes with probability $p(r)$, in which case the firm complies. Otherwise the abatement level remains r.

The key difference between Model 2 and Model 1 is that now if VA negotiations break down, the firm can still undertake self-regulation before legislation is considered.

3.1 Stage 4

If there is no negotiated agreement, then legislation to impose the optimal quota Q is considered. As in section 2 above, the regulator chooses a level of effort to devote to passage of the quota, which is implicitly defined by the function $p(r)$, which represents the regulator's optimal probability of legislation given the firm's abatement level r.

3.2 Stage 3

Suppose the parties failed to reach an agreement in stage 2. The firm's problem is now

$$\min_{r} p(r)C(Q) + (1 - p(r))C(r), \tag{5}$$

which has first-order condition

$$p'(r)[C(Q) - C(r)] + (1 - p(r))C'(r) = 0. \tag{6}$$

The value that solves (6) is R, the same as the level chosen in Model 1 when the regulator makes the offer. Note that from (2) we know that $p(Q) = 0$, and equation (6) implies $R < Q$ since otherwise the left-hand side would be positive.

3.3 Stage 2

At this stage, the player without the bargaining power chooses whether to accept or reject the other player's offer. Since failure to agree on a VA implies that the firm will self-regulate at level R in stage 3, the regulator will accept a VA at an abatement level q if

$$U(q) \geq \overline{U}(R) = p(R)U(Q) + (1 - p(R))U(R) - \gamma(p(R)).$$

The firm will accept a VA at an abatement level q if

$$C(q) \leq \overline{C}(R) = p(R)C(Q) + (1 - p(R))C(R).$$

3.4 Stage 1

At this stage, the player with the bargaining power will formulate his or her offer of an abatement level under the voluntary agreement, q^{VA}. Both players understand that if their offer is rejected at stage 2, then the firm will self-regulate at the level R. Thus, the expected payoffs in stage 2, if VA negotiations fail, are $\overline{U}(R)$ and $\overline{C}(R)$. If the parties reach an agreement in stage 2, of course, then legislation is off the table, and the firm has no reason to undertake self-regulation. Thus, it simply complies at the level q^{VA}, which is characterized below, depending upon which party has the bargaining power.

Regulator Makes the Offer If the regulator has the bargaining power, then she makes an offer that makes the firm just indifferent between signing the VA and self-regulating, as determined by

$$C(q^R(R)) = p(R)C(Q) + (1 - p(R))C(R). \tag{7}$$

Firm Makes the Offer If the firm has the bargaining power, then he makes an offer that leaves the regulator indifferent between accepting the firm's VA proposal and entering the legislative contest after the firm has self-regulated to the level R. The offer is determined by

$$U(q^F(R)) = p(R)U(Q) + (1 - p(R))U(R) - \gamma(p(R)). \tag{8}$$

Proposition 1 implies that $q^R(R) > q^F(R)$. Thus, we have the following result.

Proposition 3 *In Model 2, if the regulator has the bargaining power, then the parties sign a VA at $q^R(R)$. If the firm has the bargaining power, then they sign a VA at $q^F(R) < q^R(R)$.*

How do the outcomes of Model 2 compare with Model 1? If the regulator has the bargaining power, then the VA signed in Model 2 is the same as that signed in Model 1. If the firm has the bargaining power, then the VA signed in Model 2 is strictly more stringent than that signed in Model 1, because $q^F(R) > q^F(0)$. Thus, the two parties have conflicting preferences for the different sequences: the firm prefers Model 1, and the regulator prefers Model 2. Intuitively, the regulator wants the firm to have time to self-regulate prior to legislation, should VA negotiations break down. The firm, in contrast, wants to be able to commit not to self-regulate if negotiations break down.

It is worth noting that even if the firm has the bargaining power, the abatement required under the VA is greater than the level the firm would choose under self-regulation. If the firm has the bargaining power, he chooses q^F by setting $U(q^F(R)) = \overline{U}(R) = p(R)U(Q) + (1 - p(R))U(R) - \gamma(p(R))$. We know that $\overline{U}(R) > U(R)$ because the regulator could always choose $p(R) = 0$ and guarantee herself $U(R)$, but she finds this suboptimal, preferring to make a strictly positive effort to pass legislation. Thus, $U(q^F(R)) > U(R)$, which implies that if the firm wants to induce the regulator to sign the VA, he must offer $q^F(R) > R$. The firm is willing to do so because otherwise his expected cost would be $\overline{C}(R) = p(R)C(Q) + (1 - p(R))C(R) = C(q^R(R))$, and Proposition 1 implies that $q^R(R) > q^F(R)$. Thus, $C(q^F(R)) < \overline{C}(R)$ and the firm prefers the VA to self-regulating and taking the risk of legislation.

4 A Model with Simultaneous Moves

Given the importance of timing in determining outcomes, as shown in sections 2 and 3, this section considers a model in which the firm's decision whether to sign a contract to self-regulate, and the respondent's decision whether to sign the VA occur simultaneously. Thus the sequence of moves (note that there are now only 3 stages) is as follows:

1. The player with the bargaining power makes an offer of q^{VA}.
2. The respondent eithers signs the VA or rejects the offer, and the firm simultaneously decides whether to sign a contract to self-regulate at level r. If the VA is signed, the firm complies with the greater of r and q^{VA} and the game ends.
3. If the respondent rejects the offer, legislation is considered, and passes with probability $p(r)$, in which case the firm complies. Otherwise the abatement level remains r.

The nature of the negotiation process in this model merits further elaboration. As discussed in section 2, we think of the firm's self-regulatory choice as making a credible commitment to undertake the investment r, by making a public declaration that puts the firm's reputation at stake or signing a contract with a third-party that makes it costly for the firm to renege on the investment promise. This comports with the assumption that the firm can make its investment decision with a speed comparable to that of the regulator's decision whether to accept or reject the firm's offer. Of course, the voluntary agreement represents a commitment to the investment level q^{VA}. Thus, we assume that if $r \neq q^{VA}$, the firm will be bound by the greater of the two investment levels. Otherwise, the firm would be in violation of the more stringent commitment.[11]

4.1 Stage 3

If there is no negotiated agreement, then legislation to impose the optimal quota Q is considered. As in sections 2 and 3 above, the regulator chooses a level of effort to devote to passage of the quota, which is implicitly defined by the function $p(r)$, which represents the regulator's optimal probability of legislation given the firm's abatement level r.

[11] Section 5 takes up the issue of timing in more detail, assuming that the firm's commitment must be accomplished through sinking a physical investment rather than signing a contract.

4.2 Stage 2

At this stage, the outcome depends upon who has the bargaining power.

Regulator Makes the Offer In this case, the firm chooses a level of r, and simultaneously decides either to accept or reject the regulator's offer. The firm chooses to accept the offer if

$$C(q^R(r)) \leq p(r)C(Q) + (1 - p(r))C(r). \tag{9}$$

Now the firm's decision whether to accept the offer depends not just on q^R, but also on the firm's own choice of r. Suppose the regulator offers $q^R > q^R(R)$. This implies a cost $C(q^R) > \min_r \overline{C}(r) = \overline{C}(R)$. Thus, the firm will choose $r = R$ and reject the regulator's offer. Alternatively, suppose the regulator offers $q^R < q^R(R)$. This implies a cost $C(q^R) < \min_r \overline{C}(r) = \overline{C}(R)$. The firm will always accept this offer, and is indifferent over $r < q^R$. Finally, suppose the regulator offers $q^R(R)$. The firm will accept the offer if $r \leq R$, and reject it otherwise. If the firm rejects the offer, the parties proceed to the legislative contest, in which case the firm's expected cost is $\overline{C}(r) = p(r)C(Q)+(1-p(r))C(r)$. If the firm accepts the offer, then it is indifferent over all $r \leq q^R(R)$. If the firm rejects the offer, then it prefers to choose $r = R$, which optimally positions it for the legislative contest. Thus, if the regulator offers $q^R(R)$, the firm cannot do better than to choose $r = R$ and accept the offer. In short, it is a best response for the firm to choose $r = R$ and to accept the regulator's offer of q^R as long as $q^R \leq q^R(R)$.

Firm Makes the Offer If the firm has the bargaining power, then he makes an offer and the regulator simply chooses to accept or reject; simultaneously the firm chooses r. Consider any offer q^F by the firm. The regulator will accept if

$$U(q^F) \geq \overline{U}(r) = p(r)U(Q) + (1 - p(r))U(r) - \gamma(p(r)).$$

Thus the regulator's response depends upon what level of r she expects the firm to select. It turns out that there are two subgame-perfect equilibria in this situation. In the first, the firm offers $q^F < q^F(R)$, the regulator rejects the offer and the firm chooses $r = R$. This is an equilibrium because if the firm expects the regulator to reject the offer, then his best choice of r to prepare for the legislative contest is $r = R$, and any $q^F < q^F(R)$ is part of an equilibrium. The payoffs in this equilibrium are $\overline{U}(R)$ and $\overline{C}(R)$.

In the second type of equilibrium, the firm offers $q^F \geq q^F(0)$, the firm chooses $r = 0$, and the regulator accepts the offer. Given the firm expects the regulator to accept the offer, the firm's best response in stage 2 is to select some $r \leq q^F$. But if the regulator expects the firm to choose r, she should reject the offer if $U(q^F) < \overline{U}(r)$. So an Accept equilibrium can only exist if the firm chooses r such that $U(q^F) \geq \overline{U}(r)$, that is, if the firm offers $q^F \geq q^F(r)$. Thus, it is a best response for the firm to choose $r = 0$ in any Accept equilibrium.

Thus, when the firm makes the offer, there are two types of Nash equilibria at stage 2, one in which the regulator signs the VA and the firm chooses $r = 0$, and one in which the regulator rejects the VA and the firm chooses $r = R$.

4.3 Stage 1

Regulator Makes the Offer If the regulator has the bargaining power, she makes an offer that leaves the firm indifferent between self-regulating or complying with the VA proposal, as determined when equation (3) holds with equality. The firm will reject any offer $q^R > q^R(R)$, and will accept any offer $q^R \leq q^R(R)$. Hence the regulator's best offer is $q^R = q^R(R)$, which will be accepted.

Firm Makes the Offer As shown above, there are two subgame-perfect equilibria when the firm makes the offer. In the first, the firm offers $q^F < q^F(R)$, the regulator rejects the offer and the firm chooses $r = R$. In the second, the firm offers $q^F \geq q^F(0)$, the regulator accepts the offer and the firm chooses $r = 0$. Since $q^F(0) < q^F(R)$, offering $q^F(0)$ at stage 1 is optimal for the firm regardless of what he expects the regulator to do. Thus, we have shown the following result.

Proposition 4 *In Model 3, if the regulator has the bargaining power, a VA is signed at $q^R(R)$. If the firm has the bargaining power, there are two subgame-perfect Nash equilibria; in one a VA is signed at $q^F(0)$, and in the other no VA is signed and the firm self-regulates at $r = R$.*

If the firm has the bargaining power, then regardless of which equilibrium is expected, the firm can do no better than to offer $q^F(0)$ at Stage 1,[12] and there are two possible equilibria.

[12] One might object that the firm should be allowed to choose r in stage 1, at the same time as the initial offer is made. It turns out that this will have no effect on the outcome of the game, as long as the firm can adjust its level of self-regulation in stage 2. However, if the firm is able to invest r at stage 1, and somehow commit not to adjust it at stage 2, then we would get the results of Model 1. We consider this an implausible modeling choice, however, since the firm is assumed to be able to adjust its investment at stage 3 if legislation passes. We discuss the implications of these different modeling strategies in more detail in the following section.

Is either one of these two possible equilibria more compelling than the other? Consider in turn the possibility that $q^F(0) < R$ and then $q^F(0) > R$.

If $q^F(0) < R$, then the possible outcomes can be represented in the following normal-form game, where the firm is the row player and the regulator is the column player.[13]

	Accept	Reject
$r = 0$	$C(q^F(0)), U(q^F(0))$	$\overline{C}(0), \overline{U}(0)$
$r = R$	$C(R), U(R)$	$\overline{C}(R), \overline{U}(R)$

Note that by construction of $q^F(0)$, the regulator is indifferent between signing the VA or rejecting it if the firm is expected to play $r = 0$, that is, $U(q^F(0)) = \overline{U}(0)$. In addition, we know that $\overline{U}(R) > U(R)$. Thus, the regulator's weakly dominant strategy is Reject. The firm does not have a dominant strategy, but his best response to Reject is $r = R$.

Alternatively, if $q^F(0) > R$ the game is

	Accept	Reject
$r = 0$	$C(q^F(0)), U(q^F(0))$	$\overline{C}(0), \overline{U}(0)$
$r = R$	$C(q^F(0)), U(q^F(0))$	$\overline{C}(R), \overline{U}(R)$

Once again, the regulator's weakly dominant strategy is to Reject, because $U(q^F(0)) = \overline{U}(0)$ and $\overline{U}(R) > \overline{U}(0) = U(q^F(0))$. In addition, the firm now has a weakly dominant strategy to choose $r = R$.

Thus, regardless of whether or not $q^F(0) < R$, the regulator's weakly dominant strategy is to reject the VA. The firm's best response is to choose $r = R$. Note that this outcome is also risk dominant (Harsanyi and Selten 1988), because the product of the deviation losses from this equilibrium is greater than the product of the deviation losses from the other equilibrium. For the case where $q^F(0) < R$, the products of the deviation losses are

$$(\overline{C}(0) - \overline{C}(R))(U(R) - \overline{U}(R)) > (C(R) - C(q^F(0)))(\overline{U}(0) - U(q^F(0))).$$

Because $\overline{U}(0) - U(q^F) = 0$, the right-hand side is simply equal to zero, while the left-hand side is strictly positive. For the case where $q^F(0) > R$, the products of the deviation losses are

$$(C(q^F(0)) - \overline{C}(R))(U(q^F(0)) - \overline{U}(R)) > (C(q^F(0))) - C(q^F(0)))(\overline{U}(0) - U(q^F(0))).$$

[13] A similar matrix could be presented with a first row incorporating any r such that $\overline{U}(r) < U(q^F)$, and the results would be the same. As the alternative to the case of $r = R$, we focus on the case of $r = 0$ because it gives the firm the highest expected payoff in the case where the regulator rejects the VA.

Again the right-hand side is equal to zero. On the left-hand side, $C(q^F(0)) - \overline{C}(R) = C(q^F(0)) - C(q^R(R)) < C(q^F(R)) - C(q^R(R)) < 0$ and $U(q^F(0)) - \overline{U}(R) = \overline{U}(0) - -\overline{U}(R) < 0$, so the left-hand side is strictly positive. Thus, regardless of whether or not $q^F(0) < R$, the equilbrium in which the regulator rejects the VA is risk dominant relative to the equilibrium where the regulator accepts the VA. Intuitively, deviating from rejection may cost the regulator a large loss in utility, while deviating from acceptance imposes no risk at all. Hence, if there is a chance that the firm will choose the self-regulatory outcome, the regulator is better off to reject the VA offer.

Thus, we have the following proposition.

Proposition 5 *In Model 3, if the firm has the bargaining power, the equilibrium with a VA is eliminated via either the elimination of weakly dominated strategies or the application of the criterion of risk-dominance.*

Thus, there is a strong argument that the equilibrium in which the firm offers $q^F(0)$ and the regulator accepts is not a robust equilibrium. Instead, the regulator is better off to reject the firm's offer,and take her chances in the legislative contest. Knowing this, the firm has incentives to self-regulate to level $r = R$.

Comparing this result to Models 1 and 2 provides several insights. If the regulator has the bargaining power, the outcomes are identical across all three models. The regulator offers a VA that sets the firm's expected cost $C(q^R) = \overline{C}(r)$. Thus, in all three models, the firm's objective function is the same: minimize $\overline{C}(r)$, which has optimal solution $r = R$. However, if the firm has the bargaining power then the models have very different outcomes. In Model 1, a VA is signed at $q^F(0)$, but Model 3 shows that this equilibrium is not robust. In Model 2, the regulator obtains a VA at $q^F(R)$, while in Model 3 she rejects the firm's proposal for a weak VA, and instead lets the firm self-regulate at $r = R$, which yields the regulator utility $\overline{U}(\dot{R})$. The regulator's payoffs are the same in Models 2 and 3, but the actual play of the game is very different.

Prior models of negotiated agreements with full information always generate the result that the parties always sign a VA if the players have complete information. (Segerson and Miceli 1998; Manzini and Mariotti 2003; Glachant 2005; Dawson and Segerson 2008; Fleckinger and Glachant 2011). Ours is the first model of negotiated agreements in which a regulator with complete information may choose not to sign a VA, so it is worth discussing why in greater detail.

When the firm has the bargaining power, why does the regulator reject the VA? One can understand this from several different perspectives. First, and most simply, signing the VA is a dominated strategy for the regulator. The firm offers a weak VA at a level that makes the regulator indifferent between signing and accepting the expected utility of entering the legislative contest with no self-regulation on the part of the firm. Thus, the regulator gains nothing by signing the VA. However, rejecting the VA pays off for the regulator in the event that the firm opts to self-regulate. Second, the concept of risk dominance gives a further reason to expect the outcome to involve rejection of the firm's offer. Deviating from rejection could cost the regulator a large loss in utility, while deviating from acceptance would not. Hence, if there is a chance that the firm will choose the self-regulatory outcome, the regulator is better off to reject the offer. Third, and more subtly, when there are multiple equilibria, the regulator may be uncertain which one is being played. In such a circumstance, communication may influence the outcome that is played. (Ellingsen and Ostling 2010) The firm attempts to communicate his intention to choose $r = 0$ by making the offer $q^F(0)$. The "threat" of $r = 0$ might be enough to convince the regulator to accept the weak VA offer. However, the regulator understands that this is not just an inefficient threat, but an empty one. The regulator gains nothing by accepting the offer, and stands to gain if the firm backs down and opts to self-regulate despite his implicit threat not to do so. As a result, the regulator effectively "calls the firm's bluff." Fourth, from the perspective of evolutionary games, regulators of the "tough" type, who refuse to accept bad offers from aggressive firms, will tend to do better over time, and hence will be more likely to succeed and survive. Finally, from the perspective of experimental economics, Straub (1995) finds that the risk-dominance criterion accurately predicts play in coordination games. For all of these reasons, we expect the regulator to reject the VA offer.

5 Policy Implications

In this section, we bring together the results of the prior sections to assess the impact of voluntary agreements on social welfare. As a benchmark, we consider the case where negotiated agreements are impossible.

Proposition 6 *If there is no possibility of a negotiated agreement, then the firm invests $r = R$.*

Proof. *The result follows directly from equation (6). This is exactly the situation in Model*

2 where the firm self-regulates immediately prior to the legislative contest. ■

This benchmark result will be very useful in assessing how the possibility of offering a VA affects the regulator's payoffs. Without the possibility of a VA, the regulator's expected payoff is $\overline{U}(R)$. Another useful result is the following lemma, which establishes how the regulator's utility varies with r.

Lemma 7 *The regulator's expected utility $\overline{U}(r)$ is strictly increasing in r for $r < Q$.*

Proof. Recall that $\overline{U}(r) = p(r)U(Q) + (1 - p(r))U(r) - \gamma(p(r))$. Differentiating with respect to r yields $\overline{U}'(r) = p'(r)U(Q) + (1 - p'(r))U(r) + (1 - p(r))U'(r) - \gamma'(p(r))p'(r) = U(r) + (1 - p(r))U'(r) + p'(r)[U(Q) - U(r) - \gamma'(p(r))]$. Substituting in $U(Q) - U(r) = \gamma'(p)$ from (2) simplifies the expression to $\overline{U}'(r) = U(r) + (1 - p(r))U'(r)$, which is strictly positive for $r < Q$. ■

We are now in a position to pose the important question of whether it is possible that the ability to sign a voluntary agreement actually makes the regulator worse off, relative to a situation where signing a VA is prohibited. This question is addressed in the following proposition.

Proposition 8 *The opportunity to offer a VA is (weakly) socially beneficial except in Model 1 in the case where the firm has all the bargaining power.*

Proof. If the regulator has the bargaining power, then the equilibrium in all three models is to sign a VA at $q^R(R)$, and $U(q^R(R)) > U(q^F(R)) = \overline{U}(R)$, which implies the regulator is better off having the ability to sign a VA than she would be otherwise. If the firm has the bargaining power, then in Model 1, a VA is signed at $q^F(0)$, which is chosen by the firm to set $U(q^F(0)) = \overline{U}(0) = p(0)U(Q) + (1 - p(0))U(0) - \gamma(p(0))$. Lemma 7 then implies that $U(q^F(0)) = \overline{U}(0) < \overline{U}(R)$. Thus, the opportunity to sign the VA makes the regulator worse off than if there were no possibility of a VA. In Model 2, if the firm has the bargaining power, the regulator obtains $U(q^F(R)) = \overline{U}(R)$, and is not harmed by the opportunity to sign a VA. In Model 3, if the firm has the bargaining power, the regulator rejects the VA, and obtains $\overline{U}(R)$, exactly what she would obtain if there were no possibility of signing a VA. ■

The proposition shows that the opportunity to negotiate a VA is only socially harmful in Model 1, in the case where the firm has all the bargaining power. Our discussion of

Model 3 showed that this result is not robust to changes in the timing of moves. Intuitively, it corresponds to a dynamically inconsistent case where the firm is able to commit not to self-regulate should VA negotiations fail—even though he would prefer to self-regulate in such a situation!

How might a commitment to eschew self-regulation be made? One possibility could be that for some reason contractual commitments to make future investments are impossible, and that the firm can only credibly self-regulate by putting "steel in the ground" in an observable fashion. In this case, making any changes to an initial investment would take time. Suppose it takes the firm N periods to adjust its physical investment, and that legislation will come up for consideration at time T unless a VA has been signed. Suppose also that it takes a minimum time of Δ for a player to respond to the other player's offer. Then we could imagine a situation in which the firm makes its initial voluntary abatement investment at time t_1. The negotiation over the VA is initiated at time $t_{2,}$ and any adjustments to the firm's level of initial investment occur at time t_3. Denote the unit of elapsed time by Δ, so that that $t_3 = t_2 + \Delta = t_1 + 2\Delta$. If the firm can delay negotiations until $N > T - t_3$, then there will not be enough time to adjust his self-regulatory investment after the VA negotiations. Thus, he wants to ensure $t_3 > T - N$. However, he also wants there to be enough time to make the investment required by the VA in order to preempt the legislative threat, so he needs $t_2 < T - N$, and hence must invest by $t_1 < T - N - \Delta$. Together, these constraints imply $t_1 \in (T - N - 2\Delta, T - N - \Delta)$. Note that as $\Delta \to 0$, the window in which the firm must make its investment becomes infinitesimally small. If there is any "noise" in the firm's ability to make the investment at a specific time, e.g. because there is some risk that contractors won't finish the project on time, then the firm may miss the window. If the regulator can control the timing of the VA negotiations, then the firm cannot implement the foregoing strategy. Thus, if the firm is to make a credible commitment to not change its initial self-regulatory investment, it must have great control over its construction process and the regulator must be so weak as to be unable to control the timing of VA negotiations. This once again points out the fragile nature of the results of Model 1. Of course, if the firm's commitment is created through a public declaration or by writing a contract to self-regulate (instead of through a physical investment), then one would expect that $\Delta \simeq 0$, and there is no justification for the firm to be able to commit to its initial choice of r.

6 Numerical Example

In this section, we present the results of a simple numerical example to fix the ideas we have discussed, and to gain a better feel for the relative gains provided by a VA relative to self-regulation. Let $U(q) = q - q^2/2$, $C(q) = q^2/2$ and $\gamma(p) = p^2$. These functions meet the requirements on curvature set forth earlier in the paper. Solving $U'(Q) = 0$ implies $Q = 1$, with $U(Q) = 0.5$ and $C(Q) = 0.5$. These assumptions imply that $p(r) = (r-1)^2/4$. This means that if the firm undertakes no self-regulation, legislation will be forthcoming in equilibrium 25% of the time. In this case, the regulator's expected utility would be $\overline{U}(0) = 0.0625$ and $\overline{C}(0) = 0.125$.

The numerical results are shown in the table below.

	Model 1		Model 2		Model 3	
	Reg. offer	Firm offer	Reg. offer	Firm offer	Reg. offer	Firm offer
R	0.2192	N/A	0.2192	0.2192	0.2192	0.2192
q^R	0.4395		0.4395		0.4395	
$U(q^R)$	0.3429		0.3429		0.3429	
$C(q^R)$	0.0966		0.0966		0.0966	
q^F		0.0646		0.2496		0.0646
$U(q^F)$		0.0625		0.2184		
$C(q^F)$		0.0021		0.0311		
$\overline{U}(R)$						0.2184
$\overline{C}(R)$						0.0966

There are several things to note in the table. First, none of the models generates an outcome anywhere close to the first-best outcome. This is because the first-best is not a plausible reference point here, given that the probability of legislation absent self-regulation is only 25%.

Second, with no self-regulation, the expected regulatory requirement is 0.25, and $\overline{U}(0) = 0.0625$ and $\overline{C}(0) = 0.125$. Self-regulation changes these outcomes dramatically. The firm's expected cost falls to 0.0966, a reduction of 22.7%. The regulator's utility from self-regulation increases even more dramatically, rising to 0.2184, an increase of 249%, though admittedly starting from a low base.

Third, when the regulator has all the bargaining power, the VA that results is much more stringent than the self-regulatory level, going from 0.2192 to 0.4395, an increase of 100%.

The regulator's utility rises from 0.2184 to 0.3429, an increase of 57%. The magnitude of these improvements, of course, is due to the assumption that the regulator possesses all the bargaining power. If it were divided more equally, the VA would naturally be less stringent.

Fourth, when the firm has the bargaining power, he negotiates a VA that depends upon the model. In Model 1, the firm offers a very weak VA, at a level of abatement less than a third of the self-regulatory level; nevertheless, the weak regulator accepts the VA, obtaining a utility level only about 1/7 of the level that she would get if she could make the offer. (Again the power of holding all the bargaining power is manifest in very large changes in results from one case to another.) In Model 2, the firm makes a VA offer that is weaker than what the regulator would offer, but still greater than the self-regulatory level, and it is accepted by the regulator. In Model 3, the firm again offers a very weak VA, but this time it is rejected by the regulator, and instead the game proceeds to the legislative contest, with the regulator and the firm earning expected utilities that reflect both the possibility of legislation and the possibility that the self-regulatory level remains in place.

Fifth, in Model 1, if the firm has the bargaining power, then the regulator's utility (and hence social welfare) can be sharply reduced by the possibility of offering a VA. When the firm makes the offer, the regulator obtains only 0.0625 if she accepts the offer, while she would obtain expected utility of 0.2184 if she rejected the offer and the firm engaged in his optimal level of self-regulation. In all the other models, the regulator's utility is at least weakly greater from having the option of signing a VA.

In summary, the numerical example illustrates that self-regulation can be both highly profitable for the firm and highly beneficial for the regulator, and strongly suggests that self-regulation should not be ignored in policy discussions involving voluntary agreements. The example also illustrates that bargaining power can make a powerful difference in the stringency of the VA that is negotiated. Finally, it shows that modeling choices can have very important implications for policy analysis. If one believed Model 1 is correct, then the firm would be able to cut its costs dramatically while cutting the regulator's utility sharply. However, Model 3 shows that Model 1 is not robust, and instead implies the regulator will reject the firm's offer of a weak VA. The ability to walk away from the VA protects the regulator's utility level, and there is no need for policymakers to worry that the possibility of offering a VA will harm the regulator.

7 Conclusions

In this paper, we have examined the interaction between self-regulation and voluntary agreements in a setting that explores alternative sequences of self-regulation and VA negotiations, and alternative allocations of bargaining power between the parties. In contrast to previous research, we identified situations in which the fully-informed regulator may endogenously refuse to sign a voluntary agreement, preferring to let the firm self-regulate before proceeding to the legislative contest. We also found that the only conditions under which negotiated agreements are welfare-reducing are when (a) the regulator's bargaining power is weak, and (b) the firm can credibly commit not to increase its self-regulatory investment should negotiations with the regulator break down. Because such a commitment is not a dynamically consistent strategy for the firm, however, it is not robust to changes in the sequence of moves.

Empirical overviews such as OECD (2003), Morgenstern and Pizer (2007), and Lyon and Maxwell (2007) all find that there is scant evidence that voluntary approaches provide stronger environmental protection than would have occurred otherwise. Our model offers a new perspective on these findings: when industry can invest in self-regulation as well as negotiate a VA, it does so strategically, effectively minimizing the benefits the regulator obtains from the VA. As a result, the VA contributes little to environmental performance unless the regulator is a strong bargainer.. The empirical literature suggests that regulatory bargaining power is quite limited in practice. Nevertheless, a VA does provide a social benefit, by reducing the transaction costs of the regulatory process. In particular, a VA obviates the need to fight for legislation, thereby economizing on the regulatory effort that would have been required for passage of legislation.

An alternative perspective is to call into question the assumption that the regulator can credibly commit not to press for legislation after a VA is signed. Without this assumption, the regulator is likely to renegotiate the VA agreement, which may undermine the firm's incentives to make any investment in abatement. (The issue of renegotiation plays a prominent role in the incomplete contracts literature, as in Hart and Moore 1988 and Aghion et al. 1994.) In this case, VAs might not be negotiated at all, and we might simply observe self-regulation that is calculated to reduce the risk of future legislation. In fact, if one reads carefully the case studies in EEA (1997) and OECD (2003), one finds that few of them actually appear to embody a regulatory target backed up by a clear regulatory threat. Instead, the more common form of a VA is oriented toward providing greater flexibility in the implementation of *existing* regulations. Surprisingly, this aspect of VAs has not been explored in the theoretical literature. We leave it for future research.

More generally, we believe the literature on voluntary agreements would benefit by drawing from the contracting literature and developing a more sophisticated and nuanced analysis of when VAs will be used, and when they improve social welfare. Models that integrate self-regulation and negotiated agreements are a valuable step in this direction. We have argued that it is also necessary to take into account more of the "technological detail" (Watson 2007) of the underlying setting. In this paper we focused on issues of the timing of self-regulatory investments and VA negotiations, the duration required for the firm to complete investments, and the ability of the parties to commit to dynamically inconsistent actions. The contracts literature covers a wide range of additional considerations, including private information, contractual incompleteness, the verifiability of particular actions, and renegotiation. (Bolton and Dewatripont 2005) Indeed, if environmental performance attributes are non-contractible, then VAs may not be an appropriate means of trying to achieve them (Glachant 2007), and the more relevant question may be who will own and provide public goods. (Kotchen 2006; Besley and Ghatak 2007) Until these features are reflected in the VA literature, it will be difficult to fully assess the desirability of using voluntary agreements.

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