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by

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Abstract

Increasingly popular tailored regulation (TR) initiatives like EPA's Project XL allow plants to voluntarily substitute site-specific environmental performance standards for command-and-control regulations that dictate pollution abatement strategies. TR can significantly reduce participants' costs of complying with environmental regulations. But in doing so, it can also provide participants with a competitive advantage. We show that this can have undesirable welfare consequences when it enables relatively inefficient firms in oligopolistic markets to "steal" market share from more efficient firms. One critical determinant of whether or not TR has such adverse welfare impacts is the regulator's policy regarding the diffusion of TR agreements among non-participating firms.

Key words: tailored regulation, voluntary regulation, site-specific, performance standards, regulatory reform

JEL codes: Q28, L13, L51, K32

Non-technical abstract

The last decade has witnessed a number of efforts to modify existing regulations to give individual plants more control over pollution abatement. Chief among these is Project XL, the flagship of the U.S. Environmental Protection Agency's regulatory reinvention initiative. Participating plants are allowed to develop pollution control strategies that "replace or modify specific regulatory requirements" on the condition that these strategies improve their environmental performance. Similar programs are proliferating at the state level. We refer to such programs as "tailored regulation" (TR). Their essential features are that they are voluntary; entail a shift away from technology and process standards toward more flexible performance standards; require participating plants to demonstrate "superior environmental performance;" oblige them to pay a fixed cost to participate that arises from negotiating a performance standard, developing monitoring procedures, and in some cases investing in new pollution control equipment; and emphasize the diffusion of "regulatory innovations" developed at participating plants among non-participating plants. For firms, the main attraction of TR is the significant cost savings that can arise from being allowed to circumvent inefficient command-and-control regulations.

There are at least two reasons to believe that TR will enhance welfare. First, as just noted, TR can generate cost savings for industry. In addition, the superior environmental performance rule assures that environmental quality will not deteriorate. Notwithstanding these benefits, one troubling feature of TR is that it enables participating firms to operate under a different set of guidelines than their competitors. Therefore, intuition suggests TR could have detrimental welfare impacts by providing cost savings—and hence a competitive advantage—to selected firms.

The objective of this paper is to analyze whether and how TR can reduce social welfare compared to a command-and-control regime and to develop policy prescriptions aimed at avoiding undesirable outcomes. The paper is organized as follows. Section 2 briefly surveys the related literature on the link between voluntary regulation and competition—which by contrast mostly focuses on cost-increasing voluntary regulation—and on asymmetric cost effects in oligopoly. Section 3 develops a "generic"

modeling framework. Using this framework, Sections 4 and 5 examine the properties of TR assuming, respectively, monopoly and Cournot duopoly. Section 6 discusses policy implications.

We demonstrate that TR can reduce welfare in oligopolistic markets. Although TR always has positive impacts on consumers' surplus and on environmental quality (due to the superior environmental performance rule), it can reduce producers' surplus by lowering the production costs of relatively inefficient firms, thereby helping them "steal" market share from more efficient firms. A critical determinant of whether or not TR has such adverse welfare impacts is the regulator's policy regarding the diffusion of the cost-saving benefits of TR agreements among non-participating firms. Even if only efficient firms formally participate in TR, diffusion can enable inefficient firms to steal market share. In addition, diffusion is potentially harmful because it can dampen (or even eliminate) firms' incentives to participate in TR for the same reason that incentives to invest in conventional research and development are dampened when competing firms are able to free-ride on these investments.

Contents

Figures

1. Introduction[1]

There is a growing consensus among policy makers that command-and-control environmental regulation stifles efficiency and innovation by requiring heterogeneous plants to adopt uniform abatement strategies. While market-based instruments such as tradable permits and emissions fees address this problem, there are a variety of political and economic barriers to their immediate and widespread application. As a result, the last decade has witnessed a number of efforts to modify existing regulations to give individual plants more control over pollution abatement. Chief among these efforts at limited reform is Project XL, the flagship of the Environmental Protection Agency's regulatory reinvention initiative. Participating plants are allowed to develop pollution control strategies that "replace or modify specific regulatory requirements" on the condition that these strategies improve their environmental performance (60 FR 27282). In essence, Project XL defines voluntary site-specific performance standards that are more stringent than the *de facto* standards implied by current regulation, and grants plants "regulatory flexibility" to meet these standards in unconventional ways.

Blackman and Mazurek (in press) provides detailed descriptions of the first eight XL project to be implemented.[2] Half of these projects involve replacing complex technology standards that require plants to obtain new air permits each time their production process changes with a single plant-wide emissions cap that leaves the plants free to reconfigure their production process and to determine how to abate as long as total emissions do not exceed a predetermined limit. Each of these four XL projects involves plants in sectors where production processes change continuously and where existing technology standards and permitting requirements are particularly costly.[3]

[1] This research was funded by the Environmental Protection Agency, Office of Research and Development (grant no. R826154-01). We are grateful to Alan Krupnick, David Simpson and a discussant at the July 1999 Western Economic Association meetings for helpful comments and suggestions.
[2] A total of 15 projects were being implemented in December 1999.
[3] Of the remaining four projects described by Blackman and Mazurek (in press), three allowed plants to use unconventional methods of treating or handling hazardous waste and one involved consolidated permitting. For a detailed description of one of the most prominent Project XL agreements, see Boyd, Mazurek, Krupnick, and Blackman (1999).

Project XL has had a troubled history, in large part because of administrative problems at EPA (Caballero, 1998; Susskind et al., 1997). Nevertheless, it will almost certainly emerge as a prototype for similar efforts. President Clinton has touted it as a "regulatory blueprint for the future," a characterization that has pervaded analysis of the project (Phillips, 1995).[4] Such characterizations appear increasingly credible. In the last several years, a number of influential policy reports have called upon Congress to replace command-and-control regulation with a performance-based system (National Academy of Public Administration, 1997; Enterprise for the Environment, 1998). Towards that end, in May 1999, the Second Generation of Environmental Improvement Act was introduced in Congress to provide the legislative underpinnings for a broad-based Project XL-like program (Inside EPA, 1999). A number of such programs have already been adopted at the state level (Larsen, 1998; Kriz, 1997).

All of these programs—which we refer to as "tailored regulation" (TR)—have common characteristics which we have alluded to above: they are voluntary, i.e., plants choose whether or not to participate; they entail a shift away from technology and process standards toward more flexible performance standards; and they require participating plants to demonstrate "superior environmental performance." In addition, TR programs have two characteristics we have not yet touched upon. First, they require firms to pay a fixed cost to participate. This cost arises from negotiating a performance standard with regulators, developing monitoring procedures, and (in some cases) investing in new types of pollution control equipment. For example, Blackman and Mazurek (in press) found that the average fixed cost of putting Project XL agreements in place is approximately $325,000 per firm, not counting the costs of new pollution control equipment. Second, TR programs emphasize the diffusion of "regulatory innovations" developed at participating plants among non-participating plants. The EPA claims that diffusion is the principal aim of Project XL. The Second Generation legislation also stresses transferring the benefits of plant-specific agreements.[5]

[4] For example, the New York Times has argued that, "It is increasingly likely that the … approaches being tested [in Project XL] will eventually evolve into a new legal framework that could profoundly change the way major industries meet the nation's environmental mandates" (Cushman, 1996).
[5] EPA's website states, "[I]t is vital that each [XL] project tests new ideas with the potential for wide application and broad environmental benefits. … The goal is to … apply what is learned more broadly…" (US EPA, 1999). Similarly, the Second Generation initiative gives priority to projects that have "wide

From the point of view of firms, the main attraction of TR is the significant cost savings that can arise from being allowed to circumvent "one-size-fits-all" command-and-control regulations. While TR requires an improvement in environmental performance which would raise costs all other things equal, and which could theoretically completely offset cost savings from regulatory flexibility, the *net* impact of TR is always to reduce a participants' marginal production costs. The reason is simply that TR is voluntary, and a plant will only choose to pay a fixed participation cost if marginal costs fall. The experience of participants in Project XL confirms this logic. For example, a participating pulp manufacturing plant that was allowed to substitute plant-wide caps on air, water and hazardous waste emissions for conventional technology and effluent standards reported savings of $176,000 in permitting costs and $200,000 in materials costs in the first year of the project and predicted over $10 million in savings during the 15 year term of the agreement. Several other XL participants have reported cost savings of similar magnitudes (EPA, 1999b).[6] It is important to note that TR participants do not necessarily achieve costs savings because they adopt innovations which enable them to produce both "cheaper and cleaner." Rather, their costs fall simply because they are able to circumvent inefficient command-and-control regulations.

There are at least two reasons to believe that TR will enhance welfare. First, as just noted, TR can generate significant cost savings for industry. In addition, the superior environmental performance rule assures that environmental quality will not deteriorate. Notwithstanding these benefits, one troubling feature of TR is that it enables participating firms to operate under a different set of guidelines than their competitors. Therefore, intuition suggests TR could have detrimental welfare impacts by providing cost savings—and hence a competitive advantage—to selected firms.

In this paper, we analyze whether and how TR can reduce social welfare compared to a command-and-control regime and we develop policy prescriptions aimed at avoiding undesirable outcomes. Using a simple model of competitive interaction, we

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applicability," and requires participating plants to submit a plan for "integrating the innovations in the agreement into the Agency's standard practices to the extent practicable…" (Inside EPA, 1999).

[6] The EPA's sulfur dioxide permit trading program provides additional evidence that replacing command-and-control regulation with performance standards can generate significant cost savings. According to Burtraw (1996), in the first several year of the program when the number of actual trades was limited,

find that TR can reduce welfare in oligopolistic markets. Although TR always has positive impacts on consumers' surplus and on environmental quality (due to the superior environmental performance rule), it can reduce producers' surplus by lowering the production costs of relatively inefficient firms, thereby helping them "steal" market share from more efficient firms. A critical determinant of whether or not TR has such adverse welfare impacts is the regulator's policy regarding the diffusion of the cost-saving benefits of TR agreements among non-participating firms. Even if only efficient firms formally participate in TR, diffusion can help inefficient firms to steal market share. In addition, diffusion is potentially harmful because it can dampen (or even eliminate) firms' incentives to participate in TR for the same reason that incentives to invest in conventional research and development are dampened when competing firms are able to free-ride on these investments.

The paper is organized as follows. Section 2 briefly surveys the related literature. Section 3 develops a "generic" modeling framework. Using this framework, Sections 4 and 5 examine the properties of TR assuming, respectively, monopoly and duopoly. Section 6 sums up and concludes.

2. Literature

To our knowledge, this is the first economic analysis of voluntary site-specific performance standards. However, it contributes to a growing literature on the economics of voluntary regulation.[7] The literature has focused on three types of explanations for firms' willingness to enter into voluntary regulatory agreements. The first is that in undertaking voluntary agreements, firms seek to influence future regulation and enforcement. More specifically, they seek to preempt future regulation, to weaken it, or to encourage more stringent *de facto* regulation in order to raise rivals' costs. For example, in Maxwell, Lyon, and Hackett (1998), an entire industry collectively engages in voluntary self-regulation in order to preempt even more restrictive government-defined standards. Likewise, in Segerson and Miceli (1998), a "background legislative threat"

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participants still saved millions of dollars in compliance simply by virtue of the fact that the program replaced technology standards with performance standards.

[7] For a survey, see Lyon and Maxwell (in press).

motivates participation (along with government abatement cost subsidies and the promise of lower compliance and transactions costs).

A second explanation for participation in voluntary agreements is that firms seek to capture consumers' willingness to pay for goods produced in an environmentally friendly manner. For example, using a vertical product quality model, Arora and Gangopadhyay (1995) show that firms may voluntarily over-comply with regulatory standards in order to attract high-income green consumers (see also Garvie, 1997).

A third explanation is that firms enter into voluntary agreements because these agreements reduce production costs. This is the motivation for firms to participate in TR in our model: TR lowers firms' production costs by granting them regulatory flexibility. By contrast, almost all existing analyses concern voluntary agreements that raise production costs (Brau and Carraro, 1999).

Our model is also distinguished from the bulk of the literature on voluntary regulation by its focus on competition. We adopt this focus because, as a firm-specific cost-saving regulatory option, TR clearly can have competitive impacts. Few other papers have focused explicitly the on the link between voluntary regulation and competition. However, Brau and Carraro (1999) survey related literatures to draw some preliminary conclusions. Like us, they find that there may be a trade-off between the environmental benefits of voluntary regulation and the economic costs, although they reach these conclusions for different reasons than we do.[8]

Aside from its implications for voluntary regulation, our paper is also relevant to the literature on asymmetric cost effects in oligopolistic markets. In particular, it draws upon Carraro and Soubeyren's (1996) and Dung's (1993) analyses of how firm-specific taxes affect welfare in a Cournot oligopoly with asymmetric costs (see also Katz and Rosen, 1985 and Stern, 1987; our notation and proof strategies in Section 5.1 are particularly reminiscent of Dung, 1993). A firm-specific subsidy in these models is similar to a cost-reducing TR agreement in our model. However, in our model, firms must pay a fixed cost to get a "subsidy" and are able to freely choose whether or not to get them. Our analysis also resembles models of cost-saving technological innovation in

[8] Brau and Carraro argue that voluntary agreements may have undesirable impacts on competition by increasing concentration, promoting collusive behavior, and creating barriers to entry.

an oligopoly (e.g., Lahiri and Ono, 1988) and models of merger in an oligopoly (e.g., Farrell and Shapiro, 1990). The counter-intuitive insight from all of these papers is that in an oligopoly, lowering the production costs of relatively inefficient firms can *reduce* welfare by shifting market share away from efficient firms.

3. Generic model

This section develops a generic modeling framework which is used to analyze TR in two different market structures. In essence, we model TR as a reduction in variable production costs that firms may "purchase" for a fixed participation cost. We assume there are three types of agents: an environmental regulator, firms indexed by i, and a representative consumer. The regulator offers selected firms a choice between two regulatory regimes: command-and-control (C), and TR (T). The two regimes are indexed by $r \in (C,T)$. Each regime is defined by three variables: t^{ir}, the fixed costs paid by firm i to participate in regime r; e^{ir}, firm i's environmental performance standard under regime r; and x^{ir}, an index of firm i's variable costs under regime r *including* all of the variable costs of meeting the environmental performance standard.[9] Since, as discussed above, TR must entail a reduction in marginal production costs relative to command-and-control, we refer to x^{iT} as the "cost savings" afforded to firm i by TR. For simplicity, we normalize the command-and-control parameters to zero, that is, $t^{iC} = e^{iC} = x^{iC} = 0$. The fixed costs are exogenous, i.e., independent of the regulator's specific choice of x^{iC}. We assume that,

> Assumption 1. The regulator requires that firms participating in TR demonstrate "superior environmental performance," that is, $e^{iT} \geq 0$.

The regulator offers selected firms a take-it-or-leave-it choice between x^{iC} and x^{iT} given t^{iC} and t^{iT}. We assume that firms choose r and a level of output, q^{ir}, to maximize profit given the regulator's TR offer. That is, firms solve,

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[9] e^{iC} is the *de facto* performance standard implied by command-and-control regulation. In addition to e^{ir}, x^{ir}, and t^{ir}, the TR regime is defined by rules governing which firms are offered agreements and whether TR agreements diffuse among firms in the industry. We consider these rules in Section 5.

$$\max_{(r,q^i)} \quad \pi^{ir}(q^{ir}|x^{ir},t^{ir}) = p(Q)q^{ir} - c^i(q^{ir}|x^{ir}) - t^{ir} \qquad (1)$$

where π^{ir} is profit, $p(\cdot)$ is an inverse demand function, $Q = \sum_i q^{ir}$ is the total market quantity, and $c^i(\cdot)$ is a variable cost function. We make the following assumptions about the demand and cost functions (note that we use subscripts to denote partial derivatives and primes to denote derivatives of functions with one argument):

Assumption 2. The inverse demand function:
(i) is decreasing in market quantity ($p' < 0$)
(ii) satisfies $q^i p'' + p' < 0$.

Part (ii) is the standard stability condition for Cournot oligopoly.[10] Intuitively, it implies that the marginal revenue curve is steeper than the market demand curve.

Assumption 3. The variable cost function:
(i) is increasing and convex in q^{ir} ($c_q > 0$ and $c_{qq} > 0$)
(ii) is decreasing and convex in x^{iT} ($c_x < 0$, $c_{xx} > 0$)
(iii) marginal costs are decreasing in x^{iT} ($c_{qx} < 0$).

Firms can be thought to solve (1) by first determining the profit maximizing output for each regime, $q^{iC}*$ and $q^{iT}*$, and then comparing the maximized levels of profit for each regime, $\pi^{iC}*$ and $\pi^{iT}*$, to choose r*. Firm i's first order condition for the choice of $q^{ir}*$ is,

$$p + q^{ir}p' - c^{ir}_q = 0. \qquad (2)$$

Assumption 2(ii) is sufficient to guarantee that the second order condition is met. Firm i will choose r* = T (that is, it will participate in TR) iff,

$$\pi^{iT*}(q^{iT*}|x^{iT},t^{iT}) - \pi^{iC*}(q^{iC*}|0,0) \geq 0 \qquad (3)$$

[10] See, for example, Dung (1993), Carraro and Soubeyran (1996), and Farrell and Shapiro (1990).

The following result will prove useful in examining the welfare impacts of TR under monopoly and duopoly.

> Lemma 1. To induce a firm to participate, the regulator must offer an x^T such that variable cost savings from the TR agreement is at least as great as the fixed participation cost.

Proof: The participation constraint (3) may be written as,

$$\int_0^{x^T} \frac{d\pi^*}{dx} dx \geq t^T .$$

Using the envelope theorem,

$$\int_0^{x^T} -c_x dx \geq t^T . \qquad \text{Q.E.D.} \qquad (4)$$

It will also prove useful to define $\hat{x}^T$ to be the critical value of x^T such that (3) holds as an equality. That is,

$$\pi^{iT*}(q^{iT*}|\hat{x}^T, t^{iT}) - \pi^{iC*}(q^{iC*}|0,0) = 0 \qquad (5)$$

Thus, $\hat{x}^T$ is the cost savings that makes the firm indifferent to participation given the fixed participation costs.

4. Monopoly

To assess the effect of TR on welfare in a monopoly, we first derive the following result.

> Lemma 2. In a monopoly, participation in TR increases equilibrium output.

Proof: Totally differentiating the first order condition (2) yields,

$$\frac{dq^*}{dx} = \frac{c_{qx}}{(p'+qp''+p'-c_{qq})} > 0 \qquad (6)$$

since the numerator is negative by Assumption 3 and the denominator (the second order condition) is negative by Assumption 2. Q.E.D.

The intuition is simply that TR reduces marginal costs thereby making it profitable to increase output.

To analyze the effect of TR on welfare, we assume a representative consumer who maximizes a utility function, u(q,e). We assume the utility function is increasing and concave in both q and e ($u_q > 0$, $u_{qq} < 0$, $u_e > 0$, $u_{ee} < 0$).

Proposition 1. In a monopoly, participation in TR unambiguously increases welfare.

Proof: Given a representative consumer and a monopolistic producer, welfare, w, is given by,

$$w = u(q,e) - c(q|x^T) - t^T$$

We differentiate totally to indicate the direction in which welfare moves as a result of increases x, e, and t associated with participation in TR. Using $u_q = p$ yields,

$$dw = u_e de + \frac{dq^*}{dx}(p - c_q)dx - c_x dx - dt \quad . \qquad (7)$$

The total impact of a TR agreement is given by,

$$\int_0^{e^T} u_e de + \int_0^{x^T} \frac{dq^*}{dx}(p - c_q)dx - \int_0^{x^T} c_x dx - \int_0^{t^T} dt \, . \qquad (7')$$

The first term is non-negative by Assumption 1. The second term is positive since dq^*/dx^T is positive by Lemma 2 and since the expression in parentheses—the markup of price over marginal cost—is clearly positive. The third term is positive by Assumption 3.

Lemma 1 ensures that the sum of the third and fourth terms is positive. Thus, the total effect of TR is to increase welfare. Q.E.D.

The intuition for Proposition 1 is straightforward. The impact of TR on welfare in a monopoly can be broken down into the agreement's impacts on environmental quality, producers' surplus, and consumers' surplus. The environmental impact is always positive due to the superior environmental performance constraint. The impact on producers' surplus is always positive due to the participation constraint which ensures that TR increases the monopolist's profit. The impact on consumers' surplus is positive since TR reduces marginal costs and therefore increases equilibrium output.

Finally, we examine a monopolist's incentives to participate in TR.

Lemma 3. In a monopoly, $\hat{x}^T$, the reservation level of the TR cost savings, is increasing in t, the fixed participation cost.

Proof: We can be certain that there is only one such value of $\hat{x}^T$ since $\pi^{iT}(\cdot)$ is strictly increasing in x^T while $\pi^{iC}(\cdot)$ is constant in x^T. Taking the total derivative of (5) and using the envelope theorem yields,

$$\frac{d\hat{x}^T}{dt} = \frac{-1}{c_x} > 0. \quad \text{Q.E.D.}$$

Thus, to the extent the regulator is able to reduce the fixed participation cost, t, it can offer a lower cost savings, x^T, and still induce participation.

5. Duopoly

In this section we assume that the regulator introduces TR into a Cournot duopoly. Each duopolist's objective function is given by (1), except that now $Q = \sum_i q^{ir}$. In this version of the model, each firm's output and participation decisions depend on its competitor's decisions. In addition, these decisions depend on the way TR is administered: whether one or both firms are offered TR agreements, and whether or not TR agreements "diffuse," that is, whether firms can appropriate the cost-reducing features of their competitor's agreements without paying a fixed cost (we discuss diffusion further in Section 5.3). Regardless of how TR is administered, only a limited number of "outcomes" are possible: either zero, one, or two firms participate, and either zero, one, or two firms pay fixed costs to participate. We first examine the welfare implications of these outcomes. We then consider separately how these outcomes are determined by manner in which TR is administered. This is convenient for the sake of concise exposition, as it avoids having to repeat the derivation of welfare results.

This section is organized as follows. Section 5.1 analyzes the welfare consequences of the various outcomes. Section 5.2 considers a TR regime in which one of the two duopolists is arbitrarily selected to participate and TR agreements do not diffuse. Section 5.3 considers a TR regime in which one of the two duopolists is arbitrarily selected to participate and TR agreements diffuse costlessly. Finally, Section 5.4 examines a TR regime in which both firms are offered TR agreements.

5.1 Welfare properties of tailored regulation in a duopoly

In a heterogeneous Cournot duopoly, firms' market shares depend on their marginal costs. Hence, TR agreements that reduce marginal costs also affect market share. For example, if firm f participates in TR but firm j does not, then firm f's market share will increase and firm j's will decrease. This is illustrated in Figure 1 which depicts reaction functions for two duopolists (Carraro and Soubeyren,1996). Equilibrium is given by the intersection of the reaction functions. Graphically, a cost-reducing TR agreement lowers the slope of the participant's reaction function and, all other things equal, increases its market share. When both duopolists participate in TR, the net effect on market share will depend on the specifics of the two TR agreements.

[Insert Figure 1 here]

In order to derive welfare results, we need to first establish the impact of TR on total market output and individual firms' outputs. Regarding the first issue, we need to know whether introducing asymmetric cost-reducing TR agreements into a Cournot duopoly can reduce total market output. Is it possible that the reduction in output due to one firm's loss of market share swamps the increase in output due to its rival's gain? The answer is no.

> Proposition 2. In a Cournot duopoly, if either or both firms participate, industry output increases.

Proof: See Appendix.

Next we consider the impact of TR on a firm's own output.

> Proposition 3. In a Cournot duopoly, firm f's output will increase under TR iff: (i) firm f participates but firm j does not, or (ii) both firms participate and x^f is sufficiently large relative to x^j.

Proof: See Appendix.

The intuition for the proposition is as follows. As Figure 1 makes clear, when only one firm participates, its marginal costs fall relative to its competitor's, and its market share and output rise. When both firms participate, both firms' marginal costs fall. However, if the ratio of the two firms' marginal costs change sufficiently, the firm whose costs rise relative to its competitor's costs will lose market share. In this case, the direct positive effect of the reduction of marginal costs on output may be swamped by the indirect negative effect of the loss of market share. As a result, the firm's output may fall.

Given Propositions 2 and 3 we may now consider how TR affects welfare.

> Proposition 4. In a Cournot duopoly, TR may reduce welfare if either one or both firms participate.

Proof: Welfare is given by,

$$w = u\left(\Sigma_i q^i, e^f, e^j\right) - \Sigma_i\left\{c^i\left(q^i \middle| x^i\right) + t^i\right\}. \qquad (8)$$

Differentiating totally and using $u_Q = p$ yields,

$$dw = \left(u_e de^f + u_e de^j\right) + \left(p - c_q^f\right)dq^f - c_x^f dx^f - dt^f + \left(p - c_q^j\right)dq^j - c_x^j dx^j - dt^j. \qquad (9)$$

Using (A5) to substitute out dq^i yields,

$$\begin{aligned} dw &= \left(u_e de^f + u_e de^j\right) + \\ &\left[\left(p - c_q^f\right)\frac{\beta^f\left(1+\alpha^j\right)}{\Delta} - \left(p - c_q^j\right)\frac{\alpha^j\beta^f}{\Delta}\right]dx^f + \left[\left(p - c_q^j\right)\frac{\beta^j\left(1+\alpha^f\right)}{\Delta} - \left(p - c_q^f\right)\frac{\alpha^f\beta^j}{\Delta}\right]dx^j \qquad (10) \\ &+ \left(-c_x^f dx^f - dt^f\right) + \left(-c_x^j dx^j - dt^j\right) \end{aligned}$$

If only firm f participates, then $dx^j = dt^j = 0$, and this expression reduces to,

$$dw = \left(u_e de^f\right) + \left[\left(p - c_q^f\right)\frac{\beta^f\left(1+\alpha^j\right)}{\Delta} - \left(p - c_q^j\right)\frac{\alpha^j\beta^f}{\Delta}\right]dx^f - c_x^f dx^f - dt^f. \quad (11)$$

The total impact of TR on welfare is given by the integral of (11) over the ranges $x \in [0, x^T]$, $t \in [0, t^T]$ and $e \in [0, e^T]$ (i.e., the analog of equation 7'). The superior environmental performance constraint (Assumption 1) ensures that the integral of the first term is positive. The participation constraint (5) ensures that the sum of the integrals of the last two terms is positive. A sufficient condition for the integral of the second term to be positive is,

$$\left(p - c_q^f\right) > \alpha^j\left(c_q^f - c_q^j\right) \qquad \forall \quad x^f \in [0, x^{fT}] \qquad (12)$$

Thus, we can be certain that TR enhances welfare when firm f has lower marginal costs than firm j at $x^{fT} = 0$ (i.e., before firm f participates in TR). TR can enhance welfare even when firm f's marginal costs are higher than firm j's for some or even all values of $x^f \in [0, x^{fT}]$, as long as the marginal cost differential between the two firms is not too great. But when the cost differential between the two firms is sufficiently large, the integral of second term in (11) can be negative. If both firms participate, then from (10), the net impact on welfare depends on both the ratio of the marginal costs of the two firms and the ratio of the cost savings (x^{fT} and x^{jT}) that the firms receive. Q.E.D.

The intuition for this proposition is fairly straightforward. As in the monopoly case, the impact of TR on welfare can be broken down into its impacts on environmental quality, producers' surplus, and consumers' surplus. TR's environmental impact is always positive due to the superior environmental performance constraint. TR's impact on consumers' surplus is also always positive since Proposition 2 guarantees that TR always increases market output and therefore lowers market price. However, TR's impact on producers' surplus—the sum of the profits of the two firms—can be either positive or negative. If the impact on producers' surplus is sufficiently negative, net welfare can fall.

As noted earlier, TR agreements generally affect the firms' market shares. TR's net impact on producers' surplus will be negative when the market share loser's reduction in profit outweighs the market share winner's increase in profit. This happens when the winner has higher initial marginal costs—and therefore a lower profit margin—than the loser. In short, TR will reduce producers' surplus when it shifts production from an efficient firm to an inefficient firm. For example, when only one firm participates, it gains market share at its rival's expense. As a result, the participants' profits rise, while the rival's profits fall. As long as the participant is more efficient than its rival, the increase in the participant's profits outweighs the reduction in its rival's profits.

As noted in Section 2, this somewhat counterintuitive welfare result jibes with other literature that finds that introducing asymmetric marginal cost reductions into an oligopoly can generate reductions in producer's surplus that swamp increases in consumer's surplus. It is straightforward to generate numerical examples of this phenomenon (see Appendix).

The next three subsections explore firms' incentives to participate in TR given different sets of assumptions about which of the firms are offered TR agreements, and whether TR agreements diffuse. We use the results derived in this subsection to analyze the welfare impacts of TR in these three regulatory environments.

5.2 Duopoly with arbitrary selection and no diffusion

In this section we assume that the regulator only offers one of the two duopolists, say firm f, an opportunity to participate in TR. This assumption is meant to approximate a TR regime in which certain firms are more or less arbitrarily selected to participate, and little effort is made to ensure that the "regulatory innovations" developed under the program are diffused to other firms.

The firms' participation decision in this model is straightforward. The regulator must offer the selected firm an agreement $x^T > \hat{x}^T$ in order to induce participation (equation 5). As in the monopoly case, $\hat{x}^T$ is increasing in t.

As for social welfare, Proposition 3 dictates that if firm f participates, its output will increase. Proposition 4 dictates that welfare will increase as long as (12) holds. In other words, welfare increases as long as the ratio of firm f's marginal costs to firm j's marginal costs is sufficiently small.

5.3 Duopoly with arbitrary selection and costless diffusion

In this section, we assume that the regulator selects one of the two duopolists, firm f, to participate in TR, but also ensures that the same TR agreement costlessly diffuses to firm j. In other words, the regulator allows firm j to have the cost savings associated with the TR agreement without paying a fixed participation cost.[11] This scenario is meant to capture TR regimes in which the regulator makes a determined effort to ensure that "regulatory innovations" developed by participants are diffused throughout the industry. As noted in the introduction, both Project XL and the proposed Second Generation initiative purport to do exactly that. We first show that costless diffusion dampens incentives to participate.

> Proposition 5. In a Cournot duopoly with arbitrary selection and costless diffusion: (i) the regulator must offer a higher $\hat{x}^T$ than when diffusion does not occur; (ii) for some parameterizations of the model, the regulator may not be able to induce any participation.

Proof: Part (i): totally differentiating (5), the equation that defines $\hat{x}^T$, yields,

[11] In practice, diffusion is probably never costless. However, this assumption highlights the likely disparity in the costs of acquiring the benefits of a TR agreement faced by participants versus non-participants. In particular, non-participants will not pay many of the negotiation and transactions costs that participants do.

$$d\pi^{fT} = \left(p - c_q^f\right)dq^f + q^f dp - c_x^f d\hat{x}^f - dt^f = 0 \qquad (13)$$

since $d\pi^{fC} = 0$ if firm f does not participate. Using (2) to substitute out "p"; dp = p'dQ along with (A4) to substitute out "dp"; (A5) to substitute out "dq^f", and setting $dt^f = 0$ yields,

$$\left[-c_x^f - \frac{q^f p'\beta^f \alpha^j}{\Delta}\right] d\hat{x}^f + \left[\frac{q^f p'\beta^j(\alpha^f + 1)}{\Delta}\right] dx^j = 0\,. \qquad (14)$$

Hence,

$$\left.\frac{d\hat{x}^f}{dx^j}\right|_{\pi} = \frac{-\left[\dfrac{q^f p'\beta^j(\alpha^f + 1)}{\Delta}\right]}{\left[-c_x^f - \dfrac{q^f p'\beta^f \alpha^j}{\Delta}\right]} > 0$$

by Assumptions 2 and 3, and by (A2) and (A3). Q.E.D.

Part (ii): Beginning with (13) and using (2) to substitute out "p"; dp = p'dQ along with (A4) to substitute out "dp"; (A5) to substitute out "dq^f"; and assuming that $dx^f = dx^j$ (i.e., firm j gets the same cost savings as firm f) yields,

$$\frac{d\pi^f}{dx^f} = \frac{-\Delta c_x^f - q^f p'\beta^f(1+\alpha^j) + 1 + q^f p'\beta^j(\alpha^f + 1)}{\Delta}\,.$$

The sign of this term is ambiguous, so for certain parameterizations of the model, it may be negative. Q.E.D.

Thus, firm f's incentive to participate in TR is dampened when firm j is able to appropriate the cost savings since appropriation erodes firm f's profits. From a policy perspective, this implies that the regulator may want to limit the diffusion of TR agreements in order to encourage participation. There is a strong analogy to patents which also enhance incentives for firms to develop new products and processes by limiting the ability of competitors to free-ride. Next, we consider the welfare properties of a costless diffusion regime.

> <u>Proposition 6</u>. In a Cournot duopoly, TR with arbitrary selection and costless diffusion may reduce welfare.

Proof: Starting with (9) and setting $dx^f = dx^j$ and $t^j = 0$ yields,

$$\begin{aligned} dw &= \left(u_e de^f + u_e de^j\right) \\ &+ \left(p - c_q^f\right)dq^f - c_x^f dx^f - dt^f + \left(p - c_q^j\right)dq^j - c_x^j dx^f \end{aligned}$$

Using (A5) to substitute out dq^i yields,

$$\begin{aligned} dw &= \left(u_e de^f + u_e de^j\right) \\ &+ \frac{dx^f}{\Delta}\left\{\sum_i \beta^i\left(p - c_q^i\right) - \gamma^f\left(c_q^f - c_q^j\right)\right\} - c_x^f dx^f - dt^f - c_x^j dx^f \end{aligned}$$

where $\gamma^f \equiv \left(\alpha^j\beta^f - \alpha^f\beta^j\right) = -\gamma^j$.

The total impact of TR on welfare is given by the integral of this expression over the ranges $x \in [0, x^T]$, $t \in [0, t^T]$ and $e \in [0, e^T]$ (i.e., the analog of equation 7'). The superior environmental performance constraint (Assumption 1) ensures that the integral of the first term in parentheses is positive. The participation constraint (5) ensures that sum of the integrals of the last three terms is positive. The integral of the second term in curly brackets will be positive if,

$$\sum_i \beta^i\left(p - c_q^i\right) > \gamma^f\left(c_q^f - c_q^j\right) \qquad \forall \quad x^f \in [0, x^T].$$

This condition requires that the sum of the β-weighted markups is larger than the γ-weighted difference between the two firm's marginal costs. Note that, since the sign of γ^f may be negative, this condition can fail even when $c^f_q < c^j_q$ over the relevant range of x's—i.e., even when the firm that formally participates (firm f) is more efficient that the firm that does not (firm j). In fact, in a similar model, Dung (1993) shows that assuming linear demand and constant (but not identical) marginal costs, when firm f is more efficient that firm j, γ^f will always be negative. Q.E.D.

Thus, when diffusion is costless, TR can reduce welfare compared to the status quo by reducing producers' surplus. Moreover, TR can have this adverse effect even when only relatively efficient firms formally participate.

5.4 Duopoly with industry-wide offers

In this section, we assume that TR agreements are simultaneously offered to both competitors. Given this assumption, the participation decision is game-theoretic: each firm's participation decision affects its rival's profits and therefore each firm's participation decision depends on its rival's participation decision. In what follows, we describe the pure-strategy Nash equilibrium in the "participation game" and also explain how the terms of the TR agreement offered by the regulator determine the equilibria.

Because the participation decision in this section is complex, we make a number of assumptions to simplify the exposition. Specifically, we assume that the two firms are technologically identical, i.e.,

$$c^f(\cdot) = c^j(\cdot) \qquad \forall\, q \;\text{ for any given } x^r.$$

In addition, we assume that the two firms are offered identical agreements, i.e.,

$$x^{fT} = x^{jT}.$$

These assumptions are relatively unimportant to the results. It is straightforward, although tedious to derive equilibria in the more general case where the firms have different costs and are offered different TR agreements. Even though we assume symmetric firms and TR agreements, we will show that in equilibrium the firms need not make the same participation decision.

To simplify the notation, we use the following convention to denote firm f's profits under each regime,

$$\pi^{fr}(x^{fr}|x^{jr},t^{fr}) \qquad\qquad (r = C, T). \qquad\qquad (15)$$

The idea is to convey in as concise a manner as possible that firm f's profits depend on firm f's participation decision ($x^{fT} > 0$ versus $x^{fC} = 0$) given firm j's participation decision ($x^{jT} > 0$ versus $x^{jC} = 0$) and given the exogenous fixed participation cost associated with the regime firm f chooses ($t^{fT} > 0$ versus $t^{fC} = 0$). Using this notation, the payoffs in the participation game can be depicted as follows.

Firm j

Firm f		Don't Participate	Participate
	Don't Participate	$\pi^f(0\|0,0)$; $\pi^j(0\|0,0)$	$\pi^f(0\|x^T,0)$; $\pi^j(x^T\|0,t)$
	Participate	$\pi^f(x^T\|0,t)$; $\pi^j(0\|x^T,0)$	$\pi^f(x^T\|x^T,t)$; $\pi^j(x^T\|x^T,t)$

Given these payoffs, we may now characterize the pure-strategy Nash equilibria as a function of x^T.[12] The intuition for this analysis is that when x^T is small, neither firm will participate since small x^T's do not increase operating profit (that is revenues less variable costs) substantially but nevertheless entail a payment of t^T. By contrast, when x^T is large one or both of the firms may choose to participate. More formally, it useful to first define two critical levels of x^T which we call x_L^T and x_H^T. For a given t, let x_L^T be the x^T such that,

$$\pi^f(x^T|0,t) = \pi^f(0|0,0). \qquad (16)$$

[12] To keep the analysis simple, we do not explore mixed-strategy equilibria or equilibria in which side-payments between firms are allowed.

In other words, x^T_L is the cost savings that makes firm f just indifferent to participating given that its rival *does not* participate. Note that x^T_L is equal to $\hat{x}^T$ defined in Sections 5.2. Similarly, let x^T_H be the x^T such that,

$$\pi^f(x^T|x^T,t) = \pi^f(0|x^T,t). \qquad (17)$$

In other words, x^T_H is the cost savings that makes firm f indifferent to participation given that its rival *does* participate. We assume that t is small enough that an x^T_H exists such that firm f will participate even though firm j also participates. Given these definitions we can show that,

> Lemma 4. Firms require a larger cost reduction from TR to induce them to participate when their rival also participates, that is, $x^T_L < x^T_H$.

Proof: Since x^T_L is equal to $\hat{x}^T$ used in Section 5.2, this proposition follows directly from the proof of Proposition 5 part (i), which showed that firm f's $\hat{x}^T$ is higher when firm j participates than when firm j does not participate.

Thus, firms will accept less (privately) desirable agreements (lower x^T's) if their rivals do not participate. We can now characterize the Nash equilibria of the participation game as a function of the x^T that is offered to the firms and also of t.

> Proposition 7. There are three general types of pure-strategy Nash equilibria. Which one obtains depends on x^T as follows:
> (i) when $x^T < x^T_L$ neither firm participates,
> (ii) when $x^T > x^T_H$ both firms participate, and
> (iii) when $x^T_L < x^T < x^T_H$, only one firm participates.

Proof: The proof follows directly from the definitions of x^T_L and x^T_H.

Figure 2 summarizes the relationship between x^T and equilibria in the participation game.

[Insert Figure 2 here]

Thus, even though firms are homogeneous and are offered identical agreements, the participation game can yield asymmetric participation decisions. In particular, "intermediate" net production cost reductions ($x_L^T < x^T < x_H^T$) yield such equilibria. Asymmetric participation equilibria can be expected to occur in a variety of settings. All that is necessary is for participation to be more profitable to a firm than non-participation when its rival does not also participate.

We now examine how the fixed costs associated with participation affect the equilibria.

<u>Lemma 5</u>. Both x_L^T and x_H^T are increasing in t.

Proof: The proof, which is quite similar to that for Lemma 3, follows directly from the fact that π^f is decreasing in t.

Given Lemmas 1, 4 and 5, we can identify those combinations of x^T and t that will yield each of the three equilibria described in Proposition 7 (Figure 2). From Lemmas 4 and 5, we know that when x_L^T and x_H^T are drawn as a functions of t, both functions are increasing in t and x_L^T lies below x_H^T. In addition, Lemma 1 implies that both functions intersect the origin. Figure 2 makes clear that low values of x^T combined with high values of t will produce an equilibrium in which neither firm participates; high values of x^T combined with low values of t will produce an equilibrium in which both firms participate; and intermediate values of x^T and t will produce an equilibrium in which only one firm participates. Thus, the lower the fixed participation costs, the less (privately) desirable an agreement has to be in order to induce participation.

Finally, consider the impact on equilibria in the participation game of the costless diffusion of the TR agreement to all firms in the industry. In this case, both firms are *offered* a TR agreement but if one firm participates (i.e., pays the fixed participation cost), its rival can costlessly appropriate the cost savings. There will clearly never be a Nash equilibrium in which both firms pay the fixed participation cost, since one of the firms can always raise its profits by not paying. Hence, this scenario is substantively equivalent to that described in Section 5.3 where only one firm is offered a TR agreement, but the other firm can costlessly appropriate the benefits. The effect of diffusion is the same: it dampens incentives to participate.

6. Conclusion

We have shown that voluntary site-specific performance standards—"tailored regulation"—can reduce social welfare in certain market settings. In monopoly, TR always improves welfare: it has a positive impact on the environment, on consumers' surplus, and on producers' surplus. However, in Cournot duopoly, TR can reduce welfare: it has a positive impact on the environment and on consumers' surplus. But TR can reduce producers' surplus by helping relatively inefficient firms "steal" market share from their more efficient competitors. More precisely, TR lowers participating firms' marginal costs and therefore affects their market share (unless firms have symmetric marginal costs and get identical TR agreements). In general, one firm will lose market share and its rival will gain. Producers surplus—the sum of the firms' profits—can decline if the loser's loss outweighs the winner's gain. This occurs when the loser has relatively low marginal costs and therefore a relatively large profit margin compared to the winner.

Regulators can try to ensure that TR attracts participants and enhances welfare by carefully choosing which firms can participate, the cost savings (x^{iT}) offered to each firm, and the extent to which TR agreements are allowed to diffuse to non-participating firms. With regard to the selection of firms and the terms of the agreement, we have shown that the regulator can avoid welfare losses by ensuring that relatively inefficient firms are not singled out for participation or particularly advantageous agreements. This is more easily done in an arbitrary selection regime than in an 'industry-wide offer' regime. But even if this strategy can be successfully implemented, it has an important drawback: it implies that regulators should provide cost-breaks to market leaders, a policy that smacks of inequity and would likely run into stiff political opposition. Moreover, such a policy could result in the exit of smaller firms and increased market concentration. In this paper we have focused on demonstrating how TR can have adverse welfare impacts even abstracting from exit.[13] Nevertheless, intuition suggests that while TR administrators should ensure that inefficient firms are not the principal beneficiaries of the TR regime, they should also ensure that efficient firms are not helped to such an extent that their competitors are forced to exit the market.

Happily, in practice, even if regulators do not actively select relatively efficient firms to participate, political-economic considerations are likely to favor their participation. With in-house environmental management and lobbying capabilities and relatively easy access to investment capital, large market leaders (which are presumably relatively efficient) can more easily pay the fixed cost of participation in TR. The Project XL experience thus far would appear to confirm this hypothesis. Blackman and Mazurek (in press) found that of the first eight firms to implement XL agreements, 6 were among the top three firms in their industries in terms of market share. Does this mean that regulators can ignore the threat of welfare losses due to market stealing? Probably not. TR's emphasis on the diffusion of TR agreements among non-participants implies that inefficient firms need not formally participate in TR in order to steal market share from their competitors. And as demonstrated in Section 5.3, market stealing that results from diffusion may lead to welfare losses.

Hence, from the point of view of social welfare, the regulator's diffusion policy is critical. Diffusion has a number of potential costs. We have demonstrated that it can lead to welfare losses from market stealing, and can also dampen firms' incentives to participate. In fact, we have shown that in some situations, when diffusion is costless, it may not be possible to induce participation no matter how attractive are the terms of the TR agreement.[14] Therefore, the regulator may want to limit diffusion in order to both prevent market stealing and to generate formal participation. Widespread formal participation has clear advantages. It always has a positive impact on consumers' surplus and—assuming that performance standards under TR are more stringent than under command-and-control—on the environment.

[13] Our static model is ill-suited to an analysis of exit which is an inherently dynamic phenomenon. A model that incorporates exit would seem to be a fruitful area for future research.
[14] Given that EPA's stated policy is to diffuse the XL agreements industry-wide, it is perhaps no accident that, as described in Blackman and Mazurek (in press), Project XL has had difficulty attracting participants.

But diffusion of TR agreements clearly has economic benefits as well. It reduces firms' marginal costs and therefore inevitably enhances consumers' surplus. This benefit *may* be sufficient to offset any potential loss in producers' surplus. Hence, in setting a diffusion policy, the regulator must balance potential welfare benefits against costs. This calculation is likely to vary across industries.

Finally, our findings highlight the desirability of minimizing fixed costs of participating in TR. Given that TR agreements must reduce operating costs in order to induce participation, there is clearly a trade-off between the amount of cost-reducing regulatory flexibility an agreement entails, and the amount of environmental benefit it requires (e^{iT}). But we have seen that lower participation costs imply that regulators can induce participation with less attractive offers (lower x^T). Therefore, one means of allowing for more of each type of benefit is to find ways of reducing the fixed costs associated with participation. Although we have modeled fixed participation costs as exogenous, in practice, regulators should have some control over them. For example, in the case of Project XL, empirical research has indicated that management problems at EPA as well as uncertainty about the statutory foundation of the initiative are key contributors to participation costs, so it seems reasonable to assume that regulators have some ability to reduce these costs.

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Appendix

Proof of Proposition 2.

Totally differentiating the first order conditions (2) for each firm yields,

$$\alpha^f \Sigma_i dq^i + dq^f - \beta^f dx^f = 0 \qquad \text{(A1)}$$

$$\alpha^j \Sigma_i dq^i + dq^j - \beta^j dx^j = 0 \qquad \text{(A1')}$$

where,

$$\alpha^i = (q^i p'' + p')/(p' - c^i_{qq}) > 0 \qquad \text{(A2)}$$

by Assumptions 2 and 3. Also,

$$\beta^i = c^i_{qx}/(p' - c^i_{qq}) > 0 \qquad \text{(A3)}$$

by Assumptions 2 and 3. Summing these total differentials over both firms yields,

$$\Sigma_i \alpha^i \Sigma_i dq^i + \Sigma_i dq^i - \Sigma_i \beta^i dx^i = 0.$$

Rearranging,

$$\Sigma_i dq^i = \frac{\Sigma_i \beta^i dx^i}{\Delta} > 0 \qquad \text{(A4)}$$

where,

$$\Delta = \Sigma_i \alpha^i + 1.$$

The sum of the differentials in (A4) is positive since α^i, β^i and dx^i are all positive. Q.E.D.

Proof of Proposition 3.

Substituting (A4) into (A1) and solving for dq^f yields,

$$dq^f = \beta^f dx^f - \frac{\alpha^f \sum_i \beta^i dx^i}{\Delta}. \tag{A5}$$

If only firm f participates then,

$$\frac{dq^f}{dx^f} = \frac{\beta^f(\alpha^j + 1)}{\Delta} > 0 \tag{A6}$$

If both firms participate, then (A5) implies that $dq^f \geq 0$ iff,

$$\frac{dx^f}{dx^j} \geq \frac{\alpha^f \beta^j}{\beta^f(\alpha^j + 1)}. \text{ Q.E.D.} \tag{A7}$$

Numerical example

We show that TR agreements that lower firms' marginal costs can reduce welfare by shifting production from a relatively efficient duopolist to a relatively inefficient one. Assume linear demand and cost functions:

$$P(Q) = A - (q^f + q^j).$$

$$c(q^f) = c^f q^f - t^f$$

$$c(q^j) = c^j q^j - t^j$$

where c^f, c^j, and A are constants. Given Cournot assumptions, it is straightforward to show that equilibrium outputs are (see e.g., Jean Tirole, *The Theory of Industrial Organization*, MIT Press, 1988, pp. 218-220),

$$q^f = \frac{A - 2c^f + c^j}{3}$$

$$q^j = \frac{A - 2c^j + c^f}{3}$$

and equilibrium profits are,

$$\pi^f = \frac{[A - 2c^f + c^j]^2}{9} - t^f$$

$$\pi^j = \frac{[A - 2c^j + c^f]^2}{9} - t^j.$$

Producers' surplus is,

$$PS = (\pi^f + \pi^j)$$

and consumers' surplus is,

$$CS = \frac{[2A - c^f - c^j]^2}{18} \quad .$$

We assume that firm j participates in TR but firm f does not. Hence, firm j gets a reduction in marginal costs ($c^{jT} < c^{jC}$) and pays a fixed cost, t. For simplicity, we assume firm j is only held to a marginally higher level of environmental performance under TR, so that the environmental benefits of the TR agreement are negligible. This allows us to focus on the competition-related consequences of the agreement.

We calculate equilibrium output, profit and welfare first without the TR program and then with it. Let A = 100, $c^{fC} = 30$, $c^{jC} = 60$. Thus, the firm that participates in TR (firm j) is less efficient than its competitor. Assume further that c^{jT}=53 and t = 50.

Without the TR program, in equilibrium,

$$q^f = 33 \text{ and } q^j = 3.$$

Welfare is,

$$W = PS + CS = (1111 + 11) + 672 = \mathbf{1794}.$$

With the TR program, firm j's marginal costs fall and it gains market share:

$$q^f = 31 \text{ and } q^j = 8.$$

Note that total output rises. Welfare with TR is,

$$W = PS + CS = (961 + 14) + 761 = \mathbf{1736}.$$

Thus, welfare is lower with TR than without it despite the fact that TR reduces firm j's marginal costs. TR leads to an improvement in both consumers' surplus (761 > 672) and firm j's profits (14 > 11). But it also reduces firm f's profits (961 < 1111). This reduction in firm f's profits swamps the increase in consumers' surplus and the increase in firm j's profits. Note that the reduction in welfare (1794 -1736 = 58) is greater than the transaction costs associated with TR (t = 50).

Figure 1. Cournot reaction functions

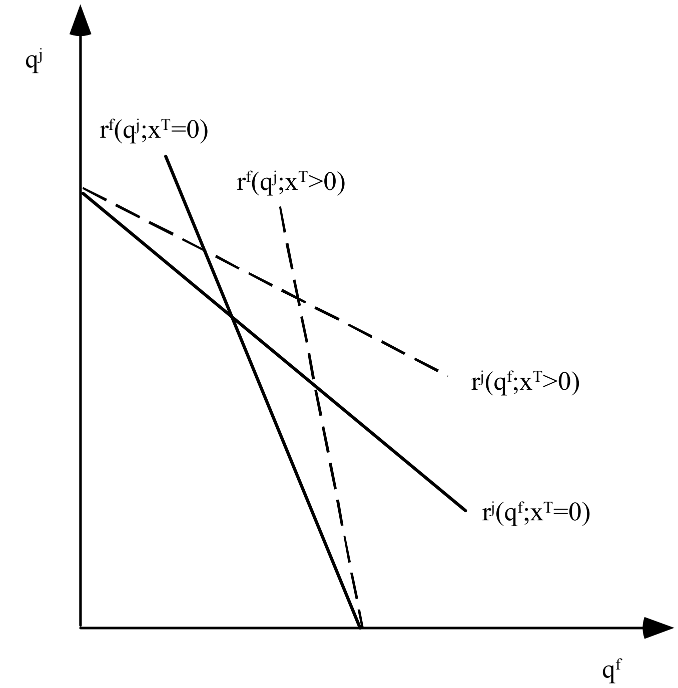

Figure 2. x_L^T and x_H^T; Participation as a function of t