E C O N O M I C S B U L L E T I N

Bankruptcy risk and the performance of tradable permit markets

John Stranlund
University of Massachusetts-Amherst

Wei Zhang
University of Massachusetts-Amherst

Abstract

We study the impacts of bankruptcy risk on markets for tradable environmental and natural resource permits. We show that bankruptcy risk in a competitive market for tradable permits causes an inefficient distribution of these permits among firms. Moreover, the equilibrium distribution of permits is dependent of the initial distribution of permits. Thus, the main reasons for implementing markets for environmental and natural resource rights do not hold when some firms are financially insecure.

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1. Introduction

Market-based polices have become an accepted approach to regulating environmental and natural resource externalities. Tradable permit policies have been designed and implemented to manage air and water pollution, fish harvests, water use, and land use (Tietenberg 2003). The fundamental value of competitive permit markets is that they produce the efficient allocation of individual rights to a resource under a fixed aggregate cap on these rights. Moreover, the equilibrium distribution of permits is independent of their initial allocation, giving regulators the freedom to use the initial allocation of permits to pursue other objectives, such as those arising from equity concerns or the exercise of political power, without upsetting the allocative efficiency property. (Montgomery 1972).

Of course, the performance of tradable permit schemes depends critically on the assumption of competitive permit trading. Hahn (1984) was the first to demonstrate that market power in an emissions trading scheme would generally lead to an inefficient distribution of emissions control responsibilities, and that the initial distribution of permits would impact the equilibrium distribution of emission control. Similarly, Stavins (1995) demonstrated that variable transaction costs associated with trading emissions permits would lead to an inefficient distribution of emissions control among regulated firms, and that this distribution of control might depend on the initial allocation of permits.

In this paper we examine how tradable permit markets perform in the presence of indebted firms who face a non-zero probability of bankruptcy, and show that financial insecurity is yet another potential source of allocative inefficiency. The key problem is the well-known limited liability effect of debt financing—firms do not consider negative returns in bankrupt states because debt holders become the residual claimants. With the continuing application of market-based policies into new environmental and natural resource settings, knowledge of how the financial health of regulated firms can impact the performance of market-based policies is an important consideration in the design and evaluation of these policies.

We are not the first to demonstrate that the financial health of firms can impact the performance of markets. For example, Brander and Lewis (1986) show that the Nash equilibrium of a model of Cournot duopolists is affected by the firms' debt levels. We are also not the first to demonstrate that bankruptcy risk may impact regulatory designs, including environmental and natural resource policies. Spiegel and Spulber (1994) investigate the interactions between the investment and financial decisions of firms and a regulator's control of their output price. Damania (2000) explores the link between pollution taxes and the financial and output decisions of firms in an oligopolistic industry, and shows that there are circumstances under which highly leveraged firms respond to pollution taxes by increasing their emissions. In a more recent work, Damania and Bulte (2005) relate the harvest decisions of firms in a fishery to the financial structure of the industry and regulatory control.

To our knowledge our work is the first to examine how bankruptcy risk and the limited liability effect impact the performance of tradable property rights regulations. We demonstrate that firms under these regulations that face a positive risk of bankruptcy will demand more permits than they would if they did not risk bankruptcy. Consequently, the decisions of financially distressed firms will cause the equilibrium distribution of permits to differ from the efficient distribution of permits. Moreover, the equilibrium distribution of permits and the allocative loss produced by financially distressed firms will depend on the initial distribution of permits. A smaller initial allocation of permits to distressed firms will increase their risk of bankruptcy and the allocative inefficiency of otherwise competitive permit trading when the aggregate demand function for permits is decreasing in the permit price. Thus, there are welfare consequences of the initial distribution of permits that are not present when permit markets do not include financially distressed firms.

2. A Model of an Indebted Firm under a Market-Based Regulation

Consider an industry whose aggregate output is limited by a tradable output permit policy. Output in our model may be interpreted as emissions of a pollutant, fish harvests, water use, or units of land development. We assume that the industry contains a fixed number of heterogeneous firms. A firm's output, q, generates profit, $\pi(q)(1+z)$, where z is a continuous random variable that is independently (but not necessarily identically) distributed in the industry. This random variable captures the effects of uncertainty on the firm's profit, such as the effects of random shifts in the demand for its output or random changes in its factor prices. The probability density function of z is $g(z)$ with support $[\underline{z}, \overline{z}]$. The expectation of z is zero so that the firm's expected profit is simply $\pi(q)$. We assume that the firm's expected profit is strictly concave and greater than zero in the relevant range of output. The value of z is revealed only after all production and permit market decisions have been made.

The firm receives an initial endowment of permits l. Each permit gives the firm the right to produce one unit of output. Enforcement of the permit program is sufficient to induce full compliance, so the firm holds the same number of output permits as its level of output. Permit trading establishes a constant price per permit p, which each firm takes as given. The firm's expenditure or revenue from permit transactions is then $p(q-l)$.

We focus the analysis on a single compliance period in which the firm's financial structure is fixed and fully captured by its debt level D.[1] Given a realization of z, the payoff to the shareholders of the firm is

$$v(q,z) = \pi(q)(1+z) - p(q-l) - D. \qquad (1)$$

If $v(q,z)$ turns out to be negative the firm declares bankruptcy and uses its earnings (if they are positive) to partially pay off its creditors. There are no other costs of declaring bankruptcy. If $v(q,z)$ turns out to be greater than zero, the firm remains solvent.

Define a critical breakeven state, $\hat{z}$, in which the firm's profit is just sufficient for it to meet its debt obligation and avoid bankruptcy:

$$\hat{z} = z \mid v(e,\hat{z}) = \pi(q)(1+\hat{z}) - p(q-l) - D = 0. \qquad (2)$$

Solving for $\hat{z}$ yields

$$\hat{z} = \left[\left(p(q-l)+D\right)/\pi(q)\right] - 1. \qquad (3)$$

If the realized value of z is greater than $\hat{z}$, the firm remains solvent, but it is insolvent if the realized value of z is less than $\hat{z}$. The probability that the firm avoids bankruptcy is the probability that $z \geq \hat{z}$; that is, $\int_{\hat{z}}^{\overline{z}} g(z)dz$. Clearly, the probability of bankruptcy increases with $\hat{z}$. Note that if $\hat{z} \leq \underline{z}$, the firm is financially secure in the sense that it does not risk bankruptcy. At the other end of the range of z, $\hat{z} \geq \overline{z}$ implies that the firm will definitely be insolvent. In this case the firm will not even bother to begin production. In the more interesting cases in which

[1] Clearly, as in Brander and Lewis (1986), we are abstracting away from the firm's capital investment decision and its mix of debt and equity financing. We do this to focus directly on how the risk of bankruptcy affects decisions in the permit market.

$\hat{z} \in (\underline{z}, \overline{z})$, the probabilities that the firm will be solvent or insolvent are both strictly between one and zero.

From (3), the first derivatives of $\hat{z}$ for $\hat{z} \in (\underline{z}, \overline{z})$ are:

$$\hat{z}_l = -p/\pi(q) < 0 \,;\; \hat{z}_D = 1/\pi(q) > 0 \,;\; \hat{z}_p = (q-l)/\pi(q) \,;\; \hat{z}_q = \left[p - \pi'(q)(1+\hat{z})\right]/\pi(q) \,. \quad (4)$$

(Derivatives are indicated by subscripts in the usual fashion). Recalling that $\pi(q) > 0$, note that an increase in the initial allocation of permits reduces the breakeven value of *z* and the probability that it will be forced to declare bankruptcy. Of course, an increase in the firm's debt payment, *D*, increases $\hat{z}$ and the probability the firm will be insolvent. The effect of a change in the price of permits on the probability of insolvency depends on whether the firm is a net buyer or net seller of permits. If the firm sells permits, an increase in the price of permits increases the value of the firm and reduces the probability that it will be bankrupt. If the firm buys permits, a price increase increases the likelihood the firm will be insolvent. Finally, the effect of the firm's level of output on the likelihood of insolvency depends on the relationship between the permit price and the firm's marginal profit evaluated at $\hat{z}$. In general the sign of $\hat{z}_q$ is indeterminate, but it easy to show that it is positive when the firm chooses its production optimally.

The manager of the firm is risk neutral and chooses the firm's output to maximize the expected value of the firm. Denote the expectation of $v(q,z)$ as $V(q,z)$. Therefore,

$$V(q,z) = \int_{\hat{z}}^{\overline{z}} \left[\pi(q)(1+z) - p(q-l) - D\right] g(z)dz \,. \quad (5)$$

Throughout we assume that $V(q,z)$ is strictly concave in *q* for every feasible value of *z*, and that the firm optimally chooses a positive level of output. Note that the manager optimizes over $(\hat{z}, \overline{z})$ instead of the whole support of *z*, because the firm earns nothing when it is bankrupt.

3. Bankruptcy Risk and a Firm's Demand for Permits

If a firm is financially secure, $\hat{z} \le \underline{z}$ and (5) reduces to $V(q) = \pi(q) - p(q-l) - D$. In this case, the firm chooses its output so that $p = \pi'(q)$, which is the familiar condition that a firm chooses its output and permit demand to equate its marginal expected profit to the going permit price. If no firm under a tradable permit program risks bankruptcy, their production choices equate their expected marginal profits. This forms the set of necessary conditions for maximizing expected industry profit, given that aggregate output is limited to some exogenous standard. Moreover, it is clear that the firms' output choices do not depend on their permit allocations.

Matters are very different if some firms risk bankruptcy. Given our assumptions that (5) is strictly concave in a firm's output and that the firm chooses positive output, the following first order condition is both necessary and sufficient to uniquely determine its optimal choice of output: $V_q = \int_{\hat{z}}^{\overline{z}} [\pi'(q)(1+z) - p] g(z)dz - \hat{z}_q g(\hat{z})[\pi(q)(1+\hat{z}) - p(q-l) - D] = 0$. Using the definition of $\hat{z}$ provided by (2), the first order condition simplifies to

$$V_q = \int_{\hat{z}}^{\overline{z}} [\pi'(q)(1+z) - p] g(z)dz = 0 \,. \quad (6)$$

Rearranging (6) gives us

$$p = \pi'(q)[1 + E(z \mid z \ge \hat{z})] \,, \quad (7)$$

where

$$E(z \mid z \ge \hat{z}) = \int_{\hat{z}}^{\overline{z}} z g(z)dz \Big/ \int_{\hat{z}}^{\overline{z}} g(z)dz \quad (8)$$

is the expectation of z (E is the expectation operator) conditional on the firm being solvent. In fact, the right hand side of (7) is the firm's expected marginal profit over states in which it avoids bankruptcy. Again, the limited bankruptcy liability of the firm causes it to choose its output to optimize only over the states in which it will be solvent.

The presence of $E(z \mid z > \hat{z})$ in (7) is an adjustment of the firm's choice of output that reflects its risk of bankruptcy. This term disappears when the risk of bankruptcy is zero. Moreover, since $\int_{\hat{z}}^{\overline{z}} zg(z)dz > \int_{\underline{z}}^{\overline{z}} zg(z)dz = 0$ when $\hat{z} \in (\underline{z}, \overline{z})$, $E(z \mid z \geq \hat{z})$ is strictly positive when the firm risks bankruptcy. This implies that a financially distressed firm will choose its output so that $p > \pi'(q)$. This implies further that, given the permit price, its output will be higher than if it did not risk bankruptcy.

The fact that a financially insecure firm does not equate its expected marginal profit to the price of permits leads directly to one of our main results about the impact of financial insecurity on the performance of competitive permit trading—a tradable permit program that contains financially insecure firms will not distribute individual output in the way that maximizes expected industry profit. Accomplishing this requires that all firms' production choices equate their individual expected marginal profits. However, firms that risk bankruptcy choose output so that their expected marginal profits are lower than the going permit price, while firms that do not risk bankruptcy choose their output to equate their expected marginal profit to the permit price. Moreover, expected marginal profits among financially distressed firms will likely differ because the values of $\hat{z}$ will vary across these firms and the densities $g(z)$ may vary as well. Since the permit market will not equate the firms' expected marginal profits, expected industry profit will not be maximized. Thus, the main reason for implementing permit trading programs does not hold in situations involving financially insecure firms.

Moreover, the distribution of individual output choices will not be independent of the initial allocation of permits, because financially distressed firms' demands for permits will depend on these allocations. To see how, obtain the comparative static $\partial q/\partial l = -V_{ql}/V_{qq}$ in the usual manner. Since $V_{qq} < 0$ by assumption, the sign of $\partial q/\partial l$ is the same as the sign of V_{ql}. Differentiate (6) with respect to l and substitute $\hat{z}_l$ from (4) into the result to obtain $V_{ql} = \left(p/\pi(q)\right)\left(\pi'(q)(1+\hat{z}) - p\right)g(\hat{z})$. To sign this, first note that $\hat{z} < E(z \mid z > \hat{z})$. Furthermore, since $\pi'(q)[1 + E(z \mid z \geq \hat{z})] - p = 0$ from (7), $\hat{z} < E(z \mid z \geq \hat{z})$ implies $\pi'(q)(1+\hat{z}) - p < 0$. This, in turn, implies $V_{ql} < 0$. Therefore, $\partial q/\partial l < 0$, indicating that a financially distressed firm's output is decreasing in its initial allocation of permits. Intuitively, an increase in a firm's allocation of permits increases the value of the firm, all else equal. Since this then reduces the firm's risk of bankruptcy, it will choose its output so that the gap between the permit price and $\pi'(q)$ is reduced. This leads to a lower level of output for a given permit price.

To complete this section, let us determine the effect of a change in the permit price on a financially distressed firm's output. As above, the comparative static $\partial q/\partial p = -V_{qp}/V_{qq}$ has the same sign as V_{qp}. From (6) and $\hat{z}_p$ from (4) obtain

$$V_{qp} = -\int_{\hat{z}}^{\overline{z}} g(z)dz - \left[(q-l)/\pi(q)\right][\pi'(q)(1+\hat{z}) - p]g(\hat{z}).$$

Note that the first term of V_{qp} is negative. However, recall that $\pi'(q)(1+\hat{z}) - p < 0$ so the sign of the second term of V_{qp} depends on whether the firm is a net buyer or seller of permits. If the firm sells permits $(q < l)$, V_{qp} and $\partial q/\partial p$ are both negative, indicating that its output is decreasing in the permit price. However, if the firm buys permits $(q > l)$, the sign of V_{qp} is indeterminate because its second term is positive. Note that it is possible that the permit demand function for a firm that simultaneously risks bankruptcy and optimally chooses to buy permits may be upward sloping. This is consistent with a result of Damania and Bulte (2005) who found that an increase in regulatory stringency to induce more conservative harvests in a fishery can lead to increased harvests by firms that risk bankruptcy. Increased regulatory stringency in our model means that the aggregate cap on output is reduced and fewer permits are issued. Under most circumstances we would expect this to increase the price of permits and lead all firms to reduce their output. However, a financially distressed firm that is a net buyer of permits may react to the reduced cap on aggregate output and increased permit price by increasing its output.

4. The Initial Allocation of Permits and the Market Effects of Bankruptcy Risk

We now examine the market effects of bankruptcy risk and limited liability, particularly the role that the initial allocation of permits plays in determining market outcomes and the allocative efficiency of competitive permit trading. We focus on the initial permit allocation for two reasons. First, decreasing the initial supply of permits to financially distressed firms increases their risk of bankruptcy, everything else equal. Therefore, we can trace out the effects of varying bankruptcy risk on permit markets by varying the initial allocation of permits. Second, since we have just demonstrated that the initial permit allocation will certainly impact permit markets when some firms risk bankruptcy, the initial allocation has efficiency consequences that cannot be ignored.

We simplify the analysis by assuming that a permit trading program contains just two types of firms. Type 1 firms do not risk bankruptcy while type 2 firms do. There are n_i identical firms of type i = 1, 2. Let l_i, q_i and π_i denote the initial allocation of permits, output, and expected profit function for each type i firm. Recall that the first order condition that determines the financially secure firms' output is $p = \pi_1'(q_1)$, which is independent of their initial allocations of permits. Thus, their equilibrium output is written as $q_1(p)$. From the strict concavity of $\pi_1(q_1)$, it is straightforward to show that $q_1(p)$ is monotonically decreasing in p. In the last section we explored how the output of the firms that risk bankruptcy depends on the permit price and their initial allocations of permits. Therefore, we write each type 2 firms' output as $q_2(p, l_2)$.

With an aggregate supply of permits equal to L, the permit market clears if and only if $n_1 q_1(p) + n_2 q_2(p, l_2) = L$. This equilibrium condition implicitly defines the equilibrium price of permits, $p(L, l_2)$. Now differentiate the identity $n_1 q_1(p(L, l_2)) + n_2 q_2(p(L, l_2), l_2) \equiv L$ with respect to l_2 to obtain the effect of the allocation of permits to the firms that risk bankruptcy on the equilibrium permit price:

$$\partial p/\partial l_2 = -n_2 \partial q_2/\partial l_2 \big/ \left[n_1 (dq_1/dp) + n_2 (\partial q_2/\partial p)\right] . \tag{9}$$

The numerator of the right hand side of (9) is positive because $\partial q_2/\partial l_2 < 0$. The denominator is the slope of the aggregate demand function for permits. In general, the impact of the permit price on the aggregate demand function is indeterminate because of the possibility that the financially insecure firms' permit demands are increasing in the permit price. For most of the rest of the analysis we assume that the aggregate demand function for permits is decreasing in the permit price, because we believe this is the most likely case in real applications. We will, however, briefly note the consequences of an upward sloping aggregate demand function at the end of this section. Under the assumption that the denominator of (9) is negative, $\partial p/\partial l_2 < 0$. This indicates that the equilibrium permit price is increasing as the allocation of permits to financially distressed firms is reduced. Consequently, increased bankruptcy risk in a market for tradable permits is likely to produce a higher permit price.

In turn, the higher permit price changes the output of financially secure and insecure firms in opposite directions. Since $dq_1/dp < 0$, reducing the initial allocation of permits for the financially insecure firms decreases the output of the financially secure firms through the increase in the permit price. Holding aggregate output to *L*, then, requires that the equilibrium response of the insecure firms to a decrease in their initial allocation of permits is that they increase their output. To demonstrate this formally, note that $\left(\partial q_2/\partial p\right)\left(\partial p/\partial l_2\right) + \partial q_2 / \partial l_2$ is the equilibrium response of a financially distressed firm to a change in its permit allocation. While we've shown that the direct effect, $\partial q_2 / \partial l_2$, is less than zero, the sign of the indirect effect, $\left(\partial q_2/\partial p\right)\left(\partial p/\partial l_2\right)$, is ambiguous because the sign of $\partial q_2/\partial p$ is ambiguous. However, the total effect is negative. To see this substitute (9) into $\left(\partial q_2/\partial p\right)\left(\partial p/\partial l_2\right) + \partial q_2 / \partial l_2$ to obtain

$$\left(\partial q_2/\partial p\right)\left(\partial p/\partial l_2\right) + \partial q_2 / \partial l_2 = \frac{n_2\left(dq_1/dp\right)\left(\partial q_2 / \partial l_2\right)}{n_1\left(dq_1/dp\right) + n_2\left(\partial q_2/\partial p\right)}. \tag{10}$$

Under the assumption that the aggregate demand for permits is downward sloping, the sign of (10) is negative because $dq_1/dp < 0$ and $\partial q_2 / \partial l_2 < 0$. Therefore, increased bankruptcy risk can increase the number of permits demanded by financially insecure firms, but decrease the number of permits demanded by financially secure firms.

Finally let us determine how the initial allocation of permits and bankruptcy risk affects expected industry profit at the aggregate cap on output. Using the equilibrium output levels for type 1 and type 2 firms, $q_1\left(p(L,l_2)\right)$ and $q_2\left(p(L,l_2),l_2\right)$, expected equilibrium industry profit is

$$\Pi = n_1\pi_1\left(q_1\left(p(L,l_2)\right)\right) + n_2\pi_2\left(q_2\left(p(L,l_2),l_2\right)\right). \tag{11}$$

The constraint on aggregate output implies $q_1\left(p(L,l_2)\right) = \left(L - n_2 q_2\left(p(L,l_2),l_2\right)\right)/n_1$. Substitute this into (11) and differentiate with respect to l_2 to obtain

$$\partial\Pi/\partial l_2 = n_2(\pi_2' - \pi_1')\left[\left(\partial q_2/\partial p\right)\left(\partial p/\partial l_2\right) + \partial q_2/\partial l_2\right]. \tag{12}$$

Recall that the firms that do not face bankruptcy choose their output so that $p = \pi_1'(q_1)$, but that firms that do risk bankruptcy choose production so that $p > \pi_2'(q_2)$. Therefore, $\pi_2' - \pi_1' < 0$ in a market equilibrium. The last term of (12) contains the equilibrium effect of changing l_2 on the output of type 2 firms, the combination of which we've just shown to be negative when the aggregate demand function is downward sloping. Therefore, $\partial\Pi/\partial l_2 > 0$ so that expected aggregate profit when holding the industry's output to *L* is increasing in the initial allocation of permits to firms that risk bankruptcy. Consequently, increased bankruptcy risk in a tradable permit market can reduce expected industry profit.

To be complete, let us briefly note how these results change if the aggregate permit demand function is increasing in the permit price at the equilibrium. In this case, a lower permit allocation to financially insecure firms actually reduces the equilibrium permit price. Consequently, the financially secure firms increase their output while the insecure firms decrease output. Moreover, the sign of $\partial\Pi/\partial l_2$ is reversed, indicating that decreasing the allocation of permits to financially insecure firms can increase industry expected profit, but only when the aggregate demand function for permits is upward sloping at the equilibrium.

5. Concluding Remarks

We have generated several policy-relevant conclusions about the impact of bankruptcy risk on the performance of market-based regulations. The most important are that the presence of bankruptcy risk reduces the allocative efficiency of competitive output permit markets, and makes the distribution of individual output choices dependent on the initial allocation of permits. Thus, the fundamental values of competitive tradable permit markets do not hold when some firms in the market risk bankruptcy. Financial insecurity, like market power and transaction costs, is yet another problem that can prevent markets in tradable property rights from fulfilling their theoretical promises.

While we have focused on the performance of tradable permit programs in this paper, our results suggest that the inefficiency associated with bankruptcy risk will also be present in other incentive-based policies, and may actually be worse. For example, policies with auctioned permits can be viewed as tradable permit programs without freely-given initial permit allocations. Since we've shown a negative relationship between the initial allocation of permits to financially insecure firms and market inefficiency when aggregate demand for permits is decreasing in the permit price, an auction, which allocates zero permits to all firms, would seem to maximize the inefficiency associated with bankruptcy risk. An output tax would produce the same result. Thus, from the singular perspective of the inefficiency caused by bankruptcy risk, the free allocation of permits to financially distressed firms may be more efficient than other incentive-based policies that do not have this feature.

One may be tempted to use our results to suggest that regulators can use the initial distribution of permits to mitigate the inefficiency associated with bankruptcy risk. However, doing so would not be a trivial undertaking. There are certainly difficulties associated with asymmetric information. A regulator must know which firms are in financial distress, which may not be readily available. Perhaps more importantly, firms may misrepresent their bankruptcy risk to obtain a greater allocation of permits. On the other hand, financially secure firms might argue convincingly that allocating more permits to insecure firms would basically be a subsidy for poorly performing firms. Finally, using the initial allocation to promote efficient permit markets would have to overcome the tendency to allocate permits by some sort of grandfathering rule. Those who would benefit from grandfathered permits would argue that this is a fair way to allocate permits, while ignoring the efficiency consequences of doing so.

There are many possible extensions of our model and results. Let us mention just a few. While we have focused on a static model of permit trading, modeling bankruptcy risk in dynamic permit markets (that may or may not allow some form of permit banking) would force us to examine the impact of financial insecurity on the efficiency of these markets over time as well as across firms. We have also assumed a fixed number of firms under a tradable property rights regulation. However, financial distress makes the endogeneity of the number of firms in an industry and the associated impacts on permit market efficiency an interesting area for future work. Finally, while we have assumed that firms fully comply with their output permits, allowing for noncompliance would likely yield interesting insights into the relationship between bankruptcy risk and compliance choices, and how these market difficulties work together to impact the performance of tradable permit programs.

References

Brander, James A. and Lewis, Tracy R. (1986) “Oligopoly and Financial Structure: The Limited Liability Effect” *American Economic Review* 76, 956-70.

Damania, Richard (2000) “Financial Structure and the Effectiveness of Pollution Control in an Oligopolistic Industry” *Resource and Energy Economics* 22, 21-36.

Damania, Richard and Erwin H. Bulte (2006) “Renewable Resource Regulation and Uncertain Prices: The Role of Financial Structure and Bankruptcy” *Resource and Energy Economics* 28, 41-43.

Hahn, Robert W. (1984) “Market Power and Transferable Property Rights” *The Quarterly Journal of Economics* 99, 753-765.

Montgomery, W. David (1972) “Markets in Licenses and Efficient Pollution Control Programs” *Journal of Economic Theory* 5, 395-418.

Spiegel, Yossef and Daniel F. Spulber (1994) “The Capital Structure of a Regulated Firm” *RAND Journal of Economics* 25, 424-40.

Stavins, Robert (1995) “Transaction Costs and Tradeable Permits” *Journal of Environmental Economics and Management* 29, 133-148.

Tietenberg, Tom H. (2003) “The Tradable-Permits Approach to Protecting the Commons: Lessons for Climate Change” *Oxford Review of Economic Policy* 19, 400-419.