Chapter 3

Environmental Policy and Market Structure

3.1 Introduction

The assumption of a competitive product market (see Baumol and Oates, 1988) is the most common one in the analysis of environmental policy, although there are some notable exceptions which assume that the product market is monopolistic (see Buchanan, 1969). Until recently much less attention has been given to the analysis of environmental policy under an oligopolistic product market. This is surprising since the assumption could be regarded as the more realistic one for describing modern industrial societies (see, for example, Ebert, 1992 and Conrad and Wang, 1993).

The basic implication of departing from the competitive market assumption is that more externalities, in addition to environmental pollution, enter the analysis. The presence of these new externalities sometimes significantly...
affect the effectiveness of environmental policy instruments (see Buchanan, 1969 and Baumol and Oates, 1998). Allowing for oligopolistic interactions introduces another layer of complexity to the analysis.

One paper that solves for the optimal emission tax in an n-firm Cournot framework is Katsoulacos and Xepapadeas (1996). They show that an increase in the emission tax decreases the Nash equilibrium values of output and increases the Nash equilibrium values of abatement expenses. They also solve for the optimal second best level of taxes. They find that under some regularity conditions, the optimal tax is less than marginal damages. This generalizes the results derived by Ebert (1992) for the monopoly case. Conrad and Wang (1993) solves for the effects of the emission tax on the output of an oligopolistic industry. In the above models firms are taken to be symmetric. In contrast Carraro and Soubeyran (1996) examine the impact of emission taxes when the firms are heterogenous.

All the preceding works, however, assume that the market structure is exogenous. This is a reasonable assumption if the firms are protected by significant barriers to entry. In the absence of such entry barriers, assuming that market structure is endogenously determined is perhaps a more reasonable assumption. In that case it is my contention that policy conclusions that hold with an exogenously given market structure need not hold when the market structure is endogenous. In this chapter I illustrate this point using a model of joint venture formation. I study the effect of the environmental policy on the incentive for joint venture formation and demonstrate that environmental policy may have some non-obvious effects on the level of pollution. Such effects arise because in my model firms endogenously de-
cide whether to form a joint venture or not, rather than taking the market structure to be exogenously given.

Since the 1980's many less developed countries (LDCs from now on) have been pursuing a policy of domestic liberalization. One of the goals behind such policies is to attract foreign multinational companies (MNCs from now on) to invest in the domestic economy. As a vehicle for such foreign participation, joint ventures are of great importance to the policy makers in the LDCs. In the recent debates over the Uruguay Round, the single European market and NAFTA, some environmentalists, however, raised concerns that trade liberalization might damage the environment. It is thus of interest to examine the interaction between environmental policy and joint venture formation.

In this chapter I develop a simple theory of joint venture formation that is based on two ingredients, synergy and moral hazard.\(^1\) In joint ventures involving a foreign MNC and a domestic LDC firm, it has often been observed that the MNC has a better access to capital, technical knowhow, management practices etc., whereas the domestic firm has a better access to labor, knowledge of local bureaucratic policies, marketing channels etc.\(^2\) Thus if a joint venture forms then the MNC will supply capital, and the domestic firm will supply labor to the joint venture, leading to a synergistic reduction in costs.

The second ingredient of the theory is moral hazard. This arises out of the fact that the amount of capital and labor the parent firms are supposed

\(^1\)The basic model draws heavily on Roy Chowdhury et al (2001).
to supply to the joint venture is not verifiable, and hence cannot be written into the contract. Hence the firms choose the level of input so as to maximize their own profit, rather than that of the joint venture. This leads to a free rider problem so that the level of input supply is less than optimum.

Thus joint ventures have two advantages over Cournot competition. First, there is the gain due to synergy, and second, by forming a joint venture the firms can avoid the dissipation of rents. However, the moral hazard problem implies that joint venture formation involves some costs as well. Depending on the relative magnitudes of these various advantages and disadvantages there can be either joint venture formation, or Cournot competition.

I examine a dirty industry where production leads to pollution, the level of pollution being monotonically related to the level of output. Since the industry is polluting, the government uses several policy measures (setting an emission standard, emission tax etc.) so as to control the pollution. All these policy measures create an pollution abatement cost, which the firms have to bear. I assume that the stricter the governmental policy, higher is the abatement cost.

I then briefly summarize the main results. My analysis shows that the emission level depends on both government regulation and market structure. If government regulation is very strict, then Cournot competition involves lesser emission compared to joint venture formation. Whereas if governmental regulation is very weak, then the joint venture involves less emission. Moreover under strict government regulation the firm will opt for Cournot competition, whereas under weak government regulation, the firms opt for joint venture formation.
Interestingly I find that if the synergistic effect is large, then stricter governmental regulations could lead to an increase in the level of emission. In this case an increase in government regulation could lead to a switch from joint venture to Cournot competition. As the industry becomes more competitive, there is an increase in aggregate output and hence in emission. However, if the synergistic effect is small then the level of emission decreases monotonically as government regulations become stricter.

The regime switch result is of interest by itself since in a study of the first 200 Fortune 500 companies, Zanetti and Abate (1993) suggest that big corporations in industrialized countries often respond to environmental policy through organizational innovations.

It is commonly accepted that with stricter pollution control measures, the level of emission in the industry will go down. My analysis demonstrates that this argument need not go through when the market structure is endogenous, in particular when the firms can decide whether to opt for joint venture or Cournot competition. This is interesting since there is evidence that even very high level of abatement taxes may fail to reduce pollution sufficiently. For example, evidence presented by the European Commission regarding the European carbon tax, based on research carried out by several research institutes, suggest that even a very high carbon tax achieves only half of the required reduction target. My analysis suggest that one possible explanation for such disappointing performance could be organizational innovations of the kind suggested by us, i.e. regime switch to a more competitive setup.

I also provide a decomposition analysis where I decompose the effects of a change in the abatement parameter on the incentive for joint venture
formation into three components, the synergistic effect, the moral hazard effect and the rent dissipation effect. I show that regime switches can be explained in terms of these effects.

I then turn to the welfare analysis. I first solve for the first best outcome when the government can dictate the market form and also the level of output of each firm. I find that the first best outcome always involves joint venture formation. I then examine if the first best outcome can be implemented when the government can only set the level of the abatement tax parameter and given the abatement tax parameter the firms endogenously decide on the market structure and the level of output. I provide necessary and sufficient conditions under which the first best outcome can be implemented. Given a market structure, I find that the optimal emission tax is always less than the marginal social damage. I find that if the industry is relatively clean then the first best outcome involves joint venture formation and this can be implemented by setting the abatement tax appropriately. However, if the industry is very polluting then the first best outcome cannot be implemented. I also demonstrate that if the government, in addition to the abatement tax, can impose lump sum taxes that are conditional on the market structure, then the first best outcome can always be implemented. Finally, I solve for the second best outcome when the first best outcome cannot be implemented.

I then relate my work in this chapter to the existing literature on the impact of environmental policy in an oligopolistic framework with an endogenous market structure. Katsoulacos and Xepapadeas (1995) consider a market where market structure is endogenously determined via a free entry condition. They show that in a homogeneous product industry with free en-
try, the optimal emission tax may exceed marginal environmental damages. To the best of my knowledge this is one of the very few works that examines the impact of environmental policy on the incentives for joint venture formation using an endogenous market structure.

The rest of the chapter is organized as follows. In the next section I describe the basic framework. Section 3 contains the analysis and some of the results. Section 4 contains a decomposition analysis. The welfare analysis is in section 5. Finally, section 6 concludes.

### 3.2 The Model

The market comprises two firms, one multinational (denoted by firm 1) and one domestic firm (denoted by firm 2) producing a homogenous product.

The market demand function is given by

\[ q = a - p, \tag{3.1} \]

where \( a > 0 \) is the parameter of market size.

There are two factors of production, capital \((K)\) and labor \((L)\). Note that capital here is a shorthand for all the inputs supplied by the foreign firm, while labor is a shorthand for all the inputs supplied by the domestic firm. The production function of both the firms are taken to be identical and of the form

\[ q = (KL)^{\frac{1}{2}}, \tag{3.2} \]
Let the per unit wage and rental cost for the MNC be $w^1$ and $r^1$ (respectively) and that for the domestic firm be $w^2$ and $r^2$ (respectively). I assume that the MNC has cheaper access to capital, while the domestic firm has cheaper access to labor. Thus

$$r^1 < r^2, \text{ and } w^1 > w^2. \quad (3.3)$$

For simplicity I assume that the game is entirely symmetric, so that

$$r^1 = w^2 = c, \text{ and } r^2 = w^1 = b, \text{ where } b > c. \quad (3.4)$$

The assumption $b > c$ reflects the fact that joint venture formation leads to a synergy in the cost structure. Thus if $c$ is small compared to $b$, then I say that the synergistic effect is large. If $c$ is close to $b$, then I say that the synergistic effect is small. Given the production function, it is standard to show that the cost function of the $i^{th}$ firm, $C_i(q_i)$ is linear in the level of output:

$$C_i(q_i) = 2\sqrt{bc}q_i, \text{ where } i = 1, 2. \quad (3.5)$$

I formalize the abatement cost as a linear function of output

$$A^i = A q_i, \quad (3.6)$$

where $A$ is the abatement cost parameter. This is a linear version of the abatement cost function used by Barrett (1994).³

³For simplicity and tractability I restrict attention to explicit functional forms for the most of my thesis. Given the clear intuitions behind most of my results, however, I feel that these should be generalizable to more complex functional forms.

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I solve for the subgame perfect Nash equilibrium of this game.

I begin by solving the profit functions of the two parent firms under joint venture formation. Under a joint venture the MNC supplies capital, and the domestic firm supplies labor, so as to take advantage of synergistic effects. However, because of moral hazard problems the partner firms can not write a contract over the amount of labor and capital that is to be supplied to the joint venture. The contract only specifies that the gross profit is to be equally divided among the two partner firms. The input costs are borne by the firm that supplies the input. Note that the moral hazard problem creates a cost for joint venture formation. It is possible, however, to consider an alternative model where there is no moral hazard problem, but joint venture formation involves some exogenous cost, e.g. cost of having a joint venture headquarters, etc. This does not affect my results qualitatively. Since this alternative formulation does not yield any additional insight I refrain from providing the calculations here.

Let $J_i$ denote the profit level of the $i$-th firm under joint venture formation. Then

\begin{align}
J_1 &= \frac{1}{2}(KL)^{\frac{1}{2}}[a - (KL)^{\frac{1}{2}} - A] - cK, \\
and \quad J_2 &= \frac{1}{2}(KL)^{\frac{1}{2}}[a - (KL)^{\frac{1}{2}} - A] - cL.
\end{align}

(3.7) (3.8)

Since the input levels under a joint venture are not contractible, I solve for the Nash equilibrium of the game, where the MNC and the domestic firm simultaneously decide on how much capital and labor to supply respectively.
The reaction functions of the two firms are given by

\[ \frac{\partial J_1}{\partial K} = \frac{1}{2} \left[ \frac{a}{2} \left( \frac{L}{K} \right)^{\frac{3}{2}} - K - \frac{A}{2} \left( \frac{L}{K} \right)^{\frac{3}{2}} \right] - c = 0, \]  
(3.9)

and

\[ \frac{\partial J_2}{\partial L} = \frac{1}{2} \left[ \frac{a}{2} \left( \frac{K}{L} \right)^{\frac{3}{2}} - K - \frac{A}{2} \left( \frac{K}{L} \right)^{\frac{3}{2}} \right] - c = 0. \]  
(3.10)

Here I restrict my attention to the symmetric equation where \( K = L \). Clearly, if I assume that the equilibrium is symmetric (i.e. \( K = L \)) then only unique solution emerges.

**Proof of Symmetry.** Suppose to the contrary there is non-symmetric equilibrium \((\overline{L}, \overline{K})\). Without loss of generality, let \( \overline{L} > \overline{K} \). Now consider equation (3.9).

\[ \frac{\partial J_1}{\partial K} = \frac{1}{2} \left[ \frac{a}{2} \left( \frac{L}{K} \right)^{\frac{3}{2}} - L - \frac{A}{2} \left( \frac{L}{K} \right)^{\frac{3}{2}} \right] - c = 0. \]

Therefore for \( \overline{L} > \overline{K} \),

\[ 0 = \frac{1}{2} \left[ \frac{a}{2} \left( \frac{\overline{L}}{\overline{K}} \right)^{\frac{3}{2}} - \overline{L} - c \right] = \frac{\overline{L}}{2} \left[ \frac{a}{2 \overline{q}} - 1 \right] - c. \]

Hence

\[ 0 > \frac{\overline{K}}{2} \left[ \frac{a}{2 \overline{q}} - 1 \right] - c. \]

However, this violates equation (3.10). Therefore by contradiction \( \overline{L} \) can not be greater than \( \overline{K} \). Hence \( \overline{L} = \overline{K} \).

Now solving equations (3.9) and (3.10) explicitly I find that:

\[ \frac{\partial J_1}{\partial K} = \frac{\partial J_2}{\partial L} = \frac{1}{2} \left[ \frac{a}{2} - K - \frac{A}{2} \right] - c = 0. \]
Therefore,

\[ \tilde{K} = \tilde{L} = \tilde{q} = \frac{a - A - 4c}{2}, \]  

(3.11)

where \( \tilde{K}, \tilde{L} \) and \( \tilde{q} \) denote the equilibrium levels of capital, labor and output respectively. Note that the equilibrium level of output and hence pollution is decreasing in \( A \).

Letting \( \tilde{J} \) denote the equilibrium level of profit for both of the partner firms

\begin{align*}
\tilde{J} &= \frac{1}{2} [(a - q)q - Aq] - r^1K \\
&= \frac{1}{4} [a - \frac{1}{2}(a - A - 4c)](a - A - 4c) - \frac{c}{2}(a - A - 4c) - \frac{A}{4}(a - A - 4c) \\
&= \frac{1}{4}(a - A - 4c)[\frac{1}{2}(2a - a + A + 4c) - 2c - A] \\
&= \frac{1}{4}(a - A - 4c)[\frac{1}{2}[a - A] \\
&= \frac{1}{8}(a - A)(a - A - 4c). \tag{3.12}
\end{align*}

I then examine the outcome under Cournot competition. Letting \( P_i \) denote the profit functions of the two firms under Cournot competition

\begin{align*}
P_1 &= (a - q_1 - q_2)q_1 - 2(bc)^{\frac{1}{2}}q_1 - Aq_1, \tag{3.13} \\
and P_2 &= (a - q_1 - q_2)q_2 - 2(bc)^{\frac{1}{2}}q_2 - Aq_2. \tag{3.14}
\end{align*}

The two first-order conditions of profit maximization yield the two reaction functions

\begin{align*}
\frac{\partial P_1}{\partial q_1} &= (a - q_1 - q_2) - q_1 - 2(bc)^{\frac{1}{2}} - A = 0, \tag{3.15} \\
\text{and} \quad \frac{\partial P_2}{\partial q_2} &= (a - q_1 - q_2) - q_2 - 2(bc)^{\frac{1}{2}} - A = 0. \tag{3.16}
\end{align*}
It is easy to show that in equilibrium $q_1 = q_2$, so that $(a-3q_1)-2(bc)^{\frac{1}{2}}-A = 0$. Letting $\bar{q}_i$ denote the equilibrium output level of the $i$-th firm

$$\bar{q}_1 = \bar{q}_2 = \bar{q} = \frac{a - A - 2(bc)^{\frac{1}{2}}}{3}. \quad (3.17)$$

Under Cournot competition also the equilibrium level of output and hence pollution is decreasing in $A$. Hence the equilibrium profit level of each Cournot firm

$$\bar{P}_1 = \bar{P}_2 = \bar{P} = [(a - 2q_1) - 2(bc)^{\frac{1}{2}} - A]q_1$$

$$= [a - \frac{2}{3}(a - A - 2(bc)^{\frac{1}{2}}) - 2(bc)^{\frac{1}{2}} - A]q_1$$

$$= \frac{1}{9}(a - A - 2(bc)^{\frac{1}{2}})^2. \quad (3.18)$$

### 3.3 The Analysis

I begin by comparing the level of pollution under joint venture and Cournot competition. Since the level of emission is monotonically related to the level of output, it is sufficient to compare the aggregate output level under joint venture and Cournot competition.

From equations (3.11) and (3.17), the aggregate output under joint venture exceeds that under Cournot competition if and only if

$$\frac{1}{2}[(a - A - 4c] > \frac{2}{3}[(a - A) - 2(bc)^{\frac{1}{2}}],$$

i.e. $3(a - A) - 12c > 4(a - A) - 8(bc)^{\frac{1}{2}},$

i.e. $8(bc)^{\frac{1}{2}} - 12c > (a - A),$

i.e. $A > a + 12c - 8(bc)^{\frac{1}{2}} = \hat{A}. \quad (3.19)$
Summarizing the above discussion I obtain my first proposition.

**Proposition 1.** If \( A > \hat{A} \), i.e. if government regulation is strict, then Cournot competition involves lesser emission. If \( A \leq \hat{A} \), i.e. if government regulation is weak, then joint venture formation involves lesser emission.

I then examine the whether the firms would prefer to opt for joint venture or Cournot competition. Obviously the firms opt for joint venture provided the profit from Cournot duopoly, \( \bar{P} \), is less than the profit under a joint venture \( \hat{J} \).

Note that I can decompose \( \hat{J} - \bar{P} \) as follows:

\[
\hat{J} - \bar{P} = [\hat{J} - \frac{M}{2}] + [\frac{M}{2} - \pi] + [\pi - \bar{P}].
\]

Here \( M \) represents the aggregate monopoly profit of the joint venture when there are no moral hazard problems, i.e. when the parent firms can write a verifiable contract over the amount of inputs to be supplied to the joint venture. \( \pi \) represents the Cournot equilibrium profit of the two firms when they can access both the inputs cheaply.

Consider the first term in square brackets, \( [\hat{J} - \frac{M}{2}] \). Note that \( \hat{J} \) represents joint venture profits when the moral hazard problem is present and \( M \) represents joint venture profits when moral hazard problems are absent. Hence this term is a measure of the moral hazard problem.

Next consider the second term in square brackets, \( [\frac{M}{2} - \pi] \). Note that this represents the difference between monopoly and Cournot profits, when under Cournot competition both the firms are as efficient as the joint venture. Thus this term is a measure of the rent dissipation effect.
Finally consider the last term in square brackets, \([\pi - \overline{P}]\). Note that this term measures the difference in Cournot profits between firms that are efficient and firms that are inefficient. Thus this term is a measure of the synergistic effect.

Thus a joint venture forms if and only if the second and the third effects outweigh the first. I will reconsider this decomposition expression explicitly later on for analyzing the intuition behind the regime switch from Joint-venture to Cournot-competition.

I now turn to an analysis of this.

From equations (3.12) and (3.18) it follows that a joint venture forms provided

\[
\widehat{J} > \overline{P}
\]

i.e. \[
\frac{1}{8}(a - A)(a - A - 4c) > \frac{1}{9}[(a - A) - 2(bc)^{\frac{1}{2}}]^2
\]

i.e. \[
\frac{1}{8}[(a - A)^2 - 4c(a - A)] > \frac{1}{9}[(a - A)^2 + 4bc - 4(a - A)(bc)^{\frac{1}{2}}]
\]

i.e. \[(a - A)^2 - 4(a - A)[9c - 8(bc)^{\frac{1}{2}}] - 32bc > 0.\] (3.20)

Next define

\[
Z(A) = (a - A)^2 - 4(a - A)[9c - 8(bc)^{\frac{1}{2}}] - 32bc,
\] (3.21)

so that \(Z(A)\) denotes the left hand side of equation (3.20). I then argue that \(Z(A)\) is decreasing in A. Note that \(Z(A)\) is decreasing in A. Note that

\[
\frac{dZ(A)}{dA} = -2(a - A) + 4[9c - 8(bc)^{\frac{1}{2}}]
\]

\[
= -2(a - A) + 4[9c - 8(bc)^{\frac{1}{2}}]
\]

\[
= -2(a - A) + 4[c + 8(c - (bc)^{\frac{1}{2}})]
\]

\[
= 2\{-(a - A) + 2[c + 8(c - (bc)^{\frac{1}{2}})]\}.\] (3.22)
Clearly, \( Z'(A) < 0 \), if and only if

\[
2[(A - a) + 2\{c + 8(c - (bc)^{\frac{1}{2}})\}] < 0,
\]

i.e. \( A < a - 2[c + 8(c - (bc)^{\frac{1}{2}})] \),

i.e. \( A < a - 2c + 16\{(bc)^{\frac{1}{2}} - c\}. \) (3.23)

Now because of synergy \( b > c \), so that \( (bc)^{\frac{1}{2}} - c \) > 0. Moreover, since the joint venture output is positive I have that \( A < a - 4c \). Moreover \( a > 4c \) is the restriction on market size. Hence \( A < a - 4c < a - 2c \). Thus \( Z'(A) < 0 \).

Hence there exists some \( A^* \) such that equation (3.20) holds if and only \( A < A^* \). (See figure 3.1).

Summarizing the above discussion I obtain my next proposition.

**Proposition 2.** For \( A > A^* \), firms opt for Cournot competition. Whereas for \( A \leq A^* \), firms opt for joint venture.

Next observe that from equation (3.20) one can write that

\[
A^* = a - 2(9c - 8\sqrt{bc}) \pm 2\sqrt{81c^2 - 144c\sqrt{bc} + 72bc}. \quad (3.24)
\]

or,

\[
A^* - a + 2(9c - 8\sqrt{bc}) = \pm 2(81c^2 - 144c\sqrt{bc} + 72bc)^{\frac{1}{2}}
\]

I then use the fact that \( Z'(A) < 0 \) to argue that the square root term must take the negative sign. This is because from equation (3.23) :

\[
A < a - 2c + 16\sqrt{bc} - c]
\]

or, \( A - a - 16\sqrt{bc} - c < -2c \)

or, \( A - a - 2[8\sqrt{bc} - 8c] < -2c \)

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or, $A - a + 2(8c - 8\sqrt{bc}) < -2c$

or, $A - a + 2(9c - 8\sqrt{bc}) - 2c < -2c$

Therefore, $A - a + 2(9c - 8\sqrt{bc}) < 0$.

Next recall that from equation (3.19) $\hat{A} = a + 12c - 8\sqrt{bc}$.

Now comparing $\hat{A}$ and $A^*$, I find

$$\hat{A} \geq A^*,$$

or, $a + 12C - 8\sqrt{bc} \geq a - 2(9c - 8\sqrt{bc}) \pm 2\sqrt{81c^2 - 144c\sqrt{bc} + 72bc},$

or, $a + (9c - 8\sqrt{bc}) + 3c \geq a - 2(9c - 8\sqrt{bc}) \pm 2\sqrt{81c^2 - 144c\sqrt{bc} + 72bc},$

or, $3(9c - 8\sqrt{bc}) + 3c \geq -2\sqrt{81c^2 - 144c\sqrt{bc} + 72bc},$

or, $15c - 12\sqrt{bc} \geq -\sqrt{81c^2 - 144c\sqrt{bc} + 72bc}$. (3.25)

There are two cases to consider.

**Case 1. $25c > 16b$.**

This implies that $15c - 12\sqrt{bc} > 0$, and hence in equation (3.25) R.H.S. $< 0 <$ L.H.S.. This in turn implies that $\hat{A} > A^*$.

**Case 2. $25c < 16b$.**

Thus in this case $15c - 12\sqrt{bc} < 0$, hence in equation (3.25) L.H.S. $< 0$. 

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Therefore, \( \hat{A} > A^* \), if and only if

\[
(15c - 12\sqrt{bc})^2 > 81c^2 - 144c\sqrt{bc} + 72bc,
\]

or,

\[
225c^2 + 144bc - 360c\sqrt{bc} > 81c^2 - 144c\sqrt{bc} + 72bc,
\]

or,

\[
144c^2 + 72bc - 216c\sqrt{bc} > 0,
\]

or,

\[
11c^2 + 18bc - 54c\sqrt{bc} > 0,
\]

or,

\[
11c + 18b > 54\sqrt{bc}.
\]

Thus when the difference between \( b \) and \( c \) is very large i.e. the synergistic effect is very large (say \( c = 0 \)), then \( \hat{A} > A^* \). Whereas if the synergistic effect is very small (the extreme case is when \( b = c \)) then \( \hat{A} < A^* \).

I then solve for the level of output as a function of \( A \), when the market structure is endogenous. There are two different cases to consider.

**Case 1.** \( \hat{A} > A^* \).

To begin with recall that the output level and consequently the level of pollution is decreasing in \( A \) under both market forms. Next note that for \( A \leq A^* \), the firms opt for joint venture formation. Moreover, joint venture involves lesser emission than Cournot competition. Whereas for \( A^* < A < \hat{A} \), the outcome involves Cournot competition, but joint venture leads to lesser emission compared to Cournot competition. (See figure 3.2). Thus in this case as \( A \) increases from \( A^* - \epsilon \), to \( A^* + \epsilon \), there is a regime switch from joint venture to Cournot competition. Thus the level of output and hence pollution goes up. Hence as governmental policy becomes more strict, the level of pollution may, in fact, increase.

Summarizing the above argument I obtain my next proposition.
**Proposition 3.** For $A > A^*$, the relation between the abatement cost and the level of emission is non-monotonic. In fact it is monotonically declining except for a upward jump at $A = A^*$.

Proposition 3 is the main result of this paper and demonstrates that an increase in the level of abatement costs (i.e. $A$) could lead to an increase in the level of pollution. This result is apparently counter-intuitive and depends on the fact that the market structure is endogenous.

**Case 2.** $A < A^*$.

Recall that the aggregate output and hence the pollution level is decreasing in $A$ as long as the market form remains unaltered. Next note that if $A < A < A^*$, then the firms opt for joint venture formation, but Cournot competition leads to lesser emission. Thus in this case as $A$ increases from $A^* - \epsilon$ to $A^* + \epsilon$, the level of output and hence pollution goes down. In fact it falls drastically at $A = A^*$, as the market structure shifts from joint venture to Cournot competition. (See figure 3.3).

Summarizing the above discussion I obtain my final proposition.

**Proposition 4.** For $A < A^*$, the level of emission is monotonically decreasing in $A$, with a downward jump at $A = A^*$.

### 3.4 Decomposition Analysis

In this section I decompose the effects of a change in the abatement parameter on the incentive for joint venture formation into three components,
synergistic effect, moral hazard effect and rent dissipation effect. This allows us to arrive at the intuition behind the regime switch from joint venture to Cournot competition.

Let us consider a hypothetical situation, where \( M \) is the monopoly profit under joint venture, when there is no moral hazard i.e.,

\[
M = \frac{(a - A - 2c)^2}{4}.
\]

Thus for each firm :

\[
\frac{M}{2} = \frac{(a - A - 2c)^2}{8}.
\]

1. Therefore the moral hazard effect :

\[
\hat{J} - \frac{M}{2} = \frac{1}{8}[(a - A)(a - A - 4c) - (a - A - 2c)^2].
\]

Thus,

\[
\hat{J} - \frac{M}{2} = \frac{1}{8}[(a - A)^2 - 4c(a - A) - (a - A)^2 + 2(a - A)2c - 4c^2]
\]

\[
= \frac{1}{8}(-4c^2)
\]

\[
= -\frac{c^2}{2}.
\]

Thus the moral hazard effect is independent of \( A \).

Again let \( \pi \) be the Cournot profit when both the firms are efficient. Therefore,

\[
\pi = \frac{1}{9}(a - A - 2c)^2.
\]
2. Therefore the rent dissipation effect:

\[
\frac{M}{2} - \pi = \frac{1}{8}(a - A - 2c)^2 - \frac{1}{9}(a - A - 2c)^2 \\
= \frac{1}{72}(a - A - 2c)^2.
\]

Therefore the rent dissipation effect is decreasing in \(A\).

3. Now the synergistic effect:

\[
\pi - \bar{\pi} = \frac{1}{9}[(a - A - 2c)^2 - (a - A - 2\sqrt{bc})^2] \\
= \frac{4}{9}(\sqrt{bc} - c)(a - A - c - \sqrt{bc}).
\]

So the synergistic effect is also decreasing in \(A\).

Recall that while both the synergistic effect and the rent-dissipation effect has a positive impact on the incentive for joint venture formation, the moral hazard effect has a negative impact. Next note that with an increase in \(A\) (induced by stricter government regulation) both the synergistic and the rent-dissipation effect decreases, whereas the moral hazard effect is independent of \(A\). Thus joint venture becomes less attractive compared to Cournot competition as government regulation gets stricter.

Finally I briefly address some robustness issues. In other related work I examine the case where the firms are asymmetric with respect to their input costs. Even in this case I demonstrate that an increase in \(A\) could lead to an increase in the level of pollution. Thus my results do not depend on the symmetry assumption.

I also extend the model to allow for R&D as well as exports by the two firms. Since I do not have the space to discuss these results in full, let me
just remark that in all these cases I find that policy conclusions that seem obvious when the market structure is exogenous, need not hold when the market structure itself is a function of the abatement cost.

3.5 The Optimal Abatement Tax

In this section I first solve for the first best outcome i.e. the optimal market structure and the output levels (which may be conditional on the market structure). The first best outcome is solved under two premises

(i) The government can dictate which market structure to follow.

(ii) The government can dictate the output level of each firm.

Having solved for the first best outcome I then examine if the first best outcome can be implemented in the following sense. Suppose that the government can only set the level of the abatement tax $A$. Given the level of $A$ the firms endogenously determine the market structure and the level of output. In such a scenario can the government ensure that the market structure and the level of output is optimal, just through manipulating $A$?

I first solve for the first best outcome. The solution is divided into two parts. I first solve for the first best outcome when the market structure is exogenously given. Thus I solve for the first best level of output under both joint venture and Cournot competition. I then solve for the first best outcome when the government can dictate the market structure as well.

Let the social damage function from pollution be given by

$$D(q_1 + q_2) = \mu(q_1 + q_2)^2,$$
where \( \mu \) denotes a parameter of social damage. Thus greater is \( \mu \), greater is the social damage for a given level of output.

I first solve for the first best outcome under Cournot competition.

**Cournot competition:** I assume that welfare is utilitarian in form. Thus it is the sum total of producers’ surplus, consumers’ surplus, the governments’ income from the abatement tax and the social damage. Hence welfare under Cournot competition is given by

\[
W_{CC} = (a - q_1 - q_2 - 2\sqrt{bc})(q_1 + q_2) + \frac{(q_1 + q_2)^2}{2} - \mu(q_1^2 + q_2^2).
\] (3.26)

Note that the term \( \frac{(q_1 + q_2)^2}{2} \) denotes the consumers’ surplus (since the aggregate output is \( q_1 + q_2 \) and the demand function is of the form \( q = a - p \)). Moreover, since the abatement tax is a transfer from the producers to the government it does not figure in the welfare function.

The first order condition for the optimal level of output under Cournot competition is given by

\[
\frac{\partial W_{CC}}{\partial q_i} = a - q_1 - q_2 - 2\sqrt{bc} - 2\mu(q_1 + q_2) = 0, \ i = 1, 2.
\]

Hence, using symmetry, I have that \( q_1 = q_2 = q_C \) satisfies

\[
q_C = \frac{a - 2\sqrt{bc}}{2(1 + 2\mu)}. \] (3.27)

Thus the aggregate level of output is \( 2q_C = \frac{a - 2\sqrt{bc}}{1 + 2\mu} \).

**Joint Venture:** I then solve for the first best level of output under a joint venture. The welfare function in this case is given by

\[
W_{JV} = (a - \sqrt{KL})\sqrt{KL} - cK - cL + \frac{KL}{2} - \mu KL.
\] (3.28)
The first order condition for the optimal level of output under a joint venture is given by

\[
\frac{\partial W_{JV}}{\partial K} = \frac{1}{2}(a - \sqrt{KL})\sqrt{\frac{L}{K}} - \frac{1}{2}\sqrt{\frac{L}{K}}\sqrt{KL} - c - \frac{L}{2} - \mu L = 0,
\]
\[
\frac{\partial W_{JV}}{\partial L} = \frac{1}{2}(a - \sqrt{KL})\sqrt{\frac{K}{L}} - \frac{1}{2}\sqrt{\frac{K}{L}}\sqrt{KL} - c - \frac{K}{2} - \mu K = 0.
\]

Using symmetry (i.e. $K = L$) the optimal outcome solves

\[
q_J = K = L = \frac{a - 2c}{1 + 2\mu}.
\]  

(3.29)

Note that the first best outcome involves joint venture formation since in this case the economy reaps the synergistic gains which are lost under Cournot competition.\(^4\)

I can summarize the above discussion to obtain my next proposition.

**Proposition 5.** (i) Under Cournot competition the first best level of output involves $\frac{a - 2\sqrt{c}}{1 + 2\mu}$.

(ii) Under a joint venture formation the first best level of output involves $\frac{a - 2c}{1 + 2\mu}$.

(iii) Under both Cournot competition and a joint venture the optimal level of output is decreasing in $\mu$.

\(^4\)To begin with note that for the same level of output, the welfare level under joint venture formation is clearly higher. This is because the level of consumers' surplus and pollution damages is the same under Cournot competition and joint venture (since the output level is the same), however, the aggregate profit under a joint venture is greater since it is more efficient due to synergistic gains. Since the welfare level under a joint venture exceeds that under Cournot competition for every level of output, the maximal level of welfare under a joint venture exceeds that under Cournot competition.
(iv) The first best level of output is greater under a joint venture.

(v) If the government can dictate the market structure as well, then he first best involves joint venture formation.

I then examine if the first best outcome characterized above can be implemented if the government cannot directly implement either the market structure or the level of output, but can use the level of the abatement parameter \( A \) as a policy tool.

I begin with two definitions.

**Definition 1.** Let \( A_J \) denote the optimal abatement tax under a joint venture. Thus \( A_J \) is that level of \( A \) for which the level of output under a joint venture is \( q_J \).

**Definition 2.** Let \( A_C \) denote the optimal abatement tax under Cournot competition. Thus \( A_C \) is that level of \( A \) such that the level of output under Cournot competition is \( q_C \) for both the firms.

I then solve for \( A_J \) and \( A_C \). Let me first solve for \( A_J \).

Recall that the equilibrium level of output under a joint venture is given by \( \frac{a - A - 4c}{2} \). The objective is to set \( A_J \) at such a level such that the equilibrium level of output under a joint venture equals the first best level, \( q_J \). Thus \( A_J \) solves the equation

\[
\frac{a - A - 4c}{2} = \frac{a - 2c}{1 + 2\mu}.
\]

Hence it follows that

\[
A_J = \frac{a(2\mu - 1) - 8\mu c}{2\mu + 1}.
\]

Clearly, \( \frac{\partial A_J}{\partial \mu} = \frac{4(a - 2c)}{(1 + 2\mu)^2} > 0. \)
I then solve for $A_C$. Recall that under Cournot competition the equilibrium level of output for both the firms is given by $\frac{a-A-2\sqrt{bc}}{3}$. The objective is to set $A_C$ at such a level such that the equilibrium level of output under Cournot competition equals the first best level, $q_C$ for both the firms. Thus $A_C$ solves the equation

$$\frac{a - A - 2\sqrt{bc}}{3} = \frac{a - 2\sqrt{bc}}{2(1 + 2\mu)}.$$ 

Hence I have that

$$A_C = \frac{(4\mu - 1)(a - 2\sqrt{bc})}{2(1 + 2\mu)}.$$ 

Thus it follows that $\frac{\partial A_C}{\partial \mu} = \frac{3(a - 2\sqrt{bc})}{(1 + 2\mu)^2} > 0$.

I then check whether the optimal values of $A_J$ and $A_C$ equals the marginal social damage or not. Note that in this case the marginal social damage equals $2\mu Q$, where $Q$ denotes the optimal level of the aggregate output.

First recall that under a joint venture $A_J = \frac{a(2\mu - 1) - 8\mu c}{2\mu + 1}$ and $2\mu Q = \frac{2\mu(a - 2\mu)}{1 + 2\mu}$. It is thus clear that under a joint venture the optimal level of tax, $A_J$ is strictly less than the marginal social damage, $\frac{2\mu(a - 2\mu)}{1 + 2\mu}$.

Next recall that under Cournot competition $A_C = \frac{(4\mu - 1)(a - 2\sqrt{bc})}{2(1 + 2\mu)}$ and $2\mu Q = \frac{2\mu(a - 2\sqrt{bc})}{1 + 2\mu}$. It is thus clear that under Cournot competition the optimal level of tax, $A_C$ is strictly less than the marginal social damage, $\frac{2\mu(a - 2\sqrt{bc})}{1 + 2\mu}$.

Thus under both market forms I find that the optimal tax rate is less than the marginal social damage evaluated at the optimal level of output. This is the same result as obtained by Buchanan (1969) in the context of monopoly, and by Katsoulacos and Xepapadeas (1996) in an oligopolistic context. The intuition is also the same. Note that under both Cournot
competition and joint venture the output level is less than optimum. Now suppose the abatement tax is set equal to the marginal damage. Then the effluent fees will reduce the already sub-optimal level of output. Thus any gain in welfare due to reduced pollution may be outweighed by the welfare loss due to reduced output. This implies that complete internalization of the external damages may not be desirable, but rather that optimal policy requires an abatement tax that is less than marginal damages.

The next proposition follows straightaway from the preceding discussion.

**Proposition 6.**

(i) Both $A_J$ and $A_C$ are increasing in $\mu$.

(ii) $A_J < A_C$.

(iii) Under a joint venture the optimal level of tax, $A_J$ is strictly less than the marginal social damage, $\frac{2\mu(a-2\sigma)}{1+2\mu}$.

(iv) Under Cournot competition the optimal level of tax, $A_C$ is strictly less than the marginal social damage, $\frac{2\mu(a-2\sqrt{\sigma})}{1+2\mu}$.

The intuition for Proposition 6(ii) is simple. Recall that under Cournot competition there is a tendency for the output level to be higher compared to that under a joint venture. Hence optimally the government sets $A_C$ to be greater than $A_J$ so as to discourage production under Cournot competition.

I then examine the conditions under which the government can implement the first best outcome. There are several cases to consider.

**Case 1.** $A_J \leq A^*$.

**Case 2.** $A^* < A_J < A_C$. 
Recall that there is joint venture formation if and only if \( A \leq A^* \). Thus in case 1 if the government sets \( A = A_J \) then the outcome involves joint venture formation. Moreover, the output is also at the first best level i.e. \( q_J \). However, in case 2 if the government sets \( A = A_J \) then the outcome involves Cournot competition and the first best outcome cannot be implemented.

Summarizing the above discussion I obtain my next proposition.

**Proposition 7.** The first best outcome can be implemented if and only if \( A_J \leq A^* \) by setting \( A = A_J \).

Recall that \( A_J \) is increasing in \( \mu \). Hence implementing the first best outcome is possible provided \( \mu \) is small, not otherwise.

As Proposition 7 demonstrates, under some parameter conditions the first best outcome cannot be implemented. There are now two natural questions to ask. First, can the first best outcome be implemented if one expands the set of feasible policies that the government is allowed to pursue? Second, if the government is not allowed to use any other policy apart from setting abatement taxes, then what is the second best level of \( A \)?

I first turn to solving the first question. Recall that the first best outcome cannot be implemented if \( A^* < A_J \). If the government sets \( A = A_J \) then the outcome involves Cournot competition, rather than joint venture formation. Now suppose the government taxes the firms if they pursue Cournot competition. If the tax is high enough then even for \( A = A_J \) there will be joint venture formation and the first best outcome is implemented. Moreover, since the tax is a transfer from firm 1 and firm 2 to the government, the welfare level is not affected. (In fact, in equilibrium, the tax is not paid at all.) Thus
if, in addition to setting the abatement tax $A$, the government is allowed to impose lump sum taxes, *that are contingent on the market structure*, then the first best outcome can always be implemented.

In fact, the first best outcome can also be implemented if the government is allowed to provide lump sum subsidies that are contingent on the market structure. In that case, however, implementing the first best may involve actually paying out subsidies. If the government is revenue constrained then such a policy may not be feasible. However, if, for political or informational reasons, such taxes are not feasible, then one must solve for the second best policies. I then turn to this task.

Consider the case where $A^* < A_J < A_c$. There are two sub cases to consider.

**Case 2(a).** If $W_{CC}(A_c) > W_{JV}(A^*)$, then the second best outcome involves setting $A = A_c$, when the outcome involves Cournot competition. (See figure 3.4.)

**Case 2(b).** If $W_{CC}(A_c) \leq W_{JV}(A^*)$, then the second best outcome involves setting $A = A^*$, when the outcome involves a joint venture. (See figure 3.5.)

### 3.6 Conclusion

In this chapter I examine the interaction between environmental policy, market structure and the level of pollution. I consider a duopoly model in a polluting industry where the firms endogenously decide whether to form a joint venture, or opt for Cournot competition. I demonstrate that if the
synergistic effect is very strong then stricter government regulations could lead to an increase in the level of pollution. The reason is that with an increase in government regulations there could be a regime switch from joint venture to Cournot competition. As the industry becomes more competitive, the aggregate output, and hence the level of pollution increases. Turning to the welfare analysis I find that the first best outcome always involves joint venture formation. I then solve for the optimal emission tax. For any given a market structure, I find that the optimal emission tax is always less than the marginal social damage. I provide necessary and sufficient conditions under which the first best outcome can be implemented. I find that if the industry is relatively clean then the first best outcome involves joint venture formation and this can be implemented by setting the abatement tax appropriately. I also solve for the second best outcome when the first best outcome cannot be implemented. In this case the structure of the optimal tax is quite interesting. I find that the optimal tax is always different from the optimal tax under a joint venture. In fact, the optimal emission tax under an endogenous market structure may be different from the optimal tax under both joint venture and Cournot competition.
Figure 3.2
Discrete upward jump in pollution

Joint Venture  Cournot Competition
Figure 3.3

Discrete downward jump in pollution

Joint Venture

Cournot Competition
Joint Venture Cournot Competition

$A^* \leq A_T \leq A_c$

$W_c(A_c) > W_T(A^*)$

Figure 3.4
Figure 3.5

\[ A^* \leq A_J < A_c \]

\[ W_c(A_c) < W_J(A^*) \]