Joint Ventures, Pollution and Environmental Policy

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Abstract

We examine the impact of abatement taxes on the pollution level in a duopoly framework with *endogenous* market structure. We demonstrate that an increase in abatement taxes could trigger a regime-switch from joint ventures to Cournot competition, causing the pollution level to *increase*. Moreover, abatement taxes can implement the first best outcome if and only if the industry is not too polluting. In case it is, the second best level of taxes may or may not equal the optimal tax under either joint venture, or Cournot competition.

Key words: Joint ventures, pollution, abatement tax, endogenous market structure.
JEL Classification No.: H23, L13.

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Acknowledgements

This paper is a thoroughly revised version of the first chapter of my thesis. I would like to thank my supervisor, Sandwip K. Das, for his comments, encouragements, and suggestions. I am also deeply indebted to Rabindranath Bhattacharya, P.R. Chowdhury, Satya P. Das, Badal Mukherji, Abhirup Sarkar, and participants at various conferences and seminars held at the Indian Statistical Institute, Jawaharlal Nehru University, and Jadavpur University for comments on earlier versions of this paper. I am also grateful to the National Institute of Public Finance and Policy for providing an ideal working environment that allowed me to complete the paper, and to Sangeeta Bansal who was kind enough to review it.

Joint Ventures, Pollution and Environmental Policy

Introduction

In this paper we examine the impact of environmental policy on the level of pollution in a dirty industry. We consider a duopoly framework where the firms endogenously decide whether to form a joint venture, or not. The emphasis is on examining the interaction between environmental policy, market structure, and the level of pollution.

Our decision to study joint ventures is motivated by the dramatic increase in the rate of joint venture formation over the last few decades.[1] In fact, with most less developed countries (LDCs) moving towards liberalization, joint ventures are of great interest to policy makers in LDCs. On the one hand, joint ventures act as a vehicle for attracting foreign multinationals (MNCs). On the other hand, in the recent debates over the Uruguay Round of the GATT, and the formation of different trade blocks like the single European market and NAFTA, concerns were raised that liberalization, with all its consequent fallouts, might damage the environment. Thus given the growing importance of joint ventures as business organizations, especially in LDCs, it is of interest to examine the interaction between environmental policy and joint ventures.

This paper also has a purely theoretical motivation, namely to study the effect of environmental policy in an oligopolistic market with an *endogenously determined market structure*. In the analysis of environmental policy, the assumption of a competitive product market is the most common one.[2] Though there is some literature which assumes that the product market is monopolistic,[3] until recently much less attention has been given to the case of oligopoly.[4]

Most of the literature with an oligopolistic market structure, however, assumes that the market structure is exogenously given. This is a reasonable assumption if the firms are protected by significant barriers to entry. In the absence of such entry barriers, however, it is, perhaps, more reasonable to assume that the market structure is endogenous. In that case we would like to argue that policy conclusions that hold with an exogenously given market structure, need not hold when the market structure is endogenous. In our model the endogeneity of the market structure arises since whether a joint venture forms or not is decided by the firms themselves.

We develop a simple theory of joint venture formation that is based on two ingredients, synergy and moral hazard. In joint ventures involving a foreign MNC and a domestic firm from a LDC, it has often been observed that the MNC has better access to capital, technical knowhow, management practices etc., whereas the domestic firm has better access to labour, knowledge of local bureaucratic policies, marketing channels etc.[5] Thus if a joint venture forms then the MNC will supply capital, and the domestic firm will supply labour to the joint venture,[6] 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 labour supplied by the parent firms 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 maximise 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 venture formation has two advantages over Cournot competition. First, there is the gain due to synergy, and second, by forming a joint venture the firms can avoid 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 effects there can be either joint venture formation, or Cournot competition.

We examine a dirty industry where production leads to pollution, the level of pollution being monotonically related to the level of output. The government uses several policy measures (e.g. imposing emission taxes etc.) so as to control the pollution. All these policy measures create an abatement cost for the firms. Clearly the stricter the governmental policy, the higher is the abatement cost.

We then briefly summarise our main results. Our analysis shows that the pollution level depends on both government regulation and market structure. If government regulation is very strict, then Cournot competition involves lesser pollution compared to joint venture formation. Whereas if governmental regulation is very weak, then joint venture formation involves less pollution. Moreover, under strict government regulation, the firms will opt for Cournot competition, whereas under weak government regulation, the firms opt for joint venture formation.

Interestingly we find that if the synergistic effect is large, then stricter governmental regulations could lead to an increase in the level of pollution. In this case an increase in government regulation could lead to a regime switch from joint venture to Cournot competition. As the industry becomes more competitive, there is an increase in aggregate output and hence in pollution. Clearly, the result is driven by the endogeneity of the market structure, and buttresses our earlier contention that while analysing environmental policy, the issue of market structure needs to be addressed very carefully.

The regime switch result is also of interest by itself since, in a study of the first 200 Fortune 500 companies by Zanetti and Abate (1993), it is argued that in industrialised countries big corporations often respond to environmental policy through organizational innovations. Moreover, there is some evidence that even very high level of abatement taxes may fail to reduce pollution levels sufficiently.[7] Our analysis suggests that one possible explanation could be that such high level of abatement taxes causes a switch to a more polluting market structure.

If, however, the synergistic effect is small, then we find that the level of pollution decreases monotonically as government regulation becomes stricter.

Turning to the welfare analysis we find that the first best outcome always involves joint venture formation. We then examine if the first best outcome can be implemented when the government can only set the abatement tax. We find that if the industry is relatively clean, then the first best outcome can be implemented by setting the abatement tax appropriately. However, if the industry is very polluting, then the first best outcome cannot be implemented. Given a market structure, we demonstrate that the optimal abatement tax is always less than the marginal social damage.[8] Finally, we solve for the second best outcome when the first best outcome cannot be implemented. Interestingly, the second best abatement tax may be different from the optimal tax under both joint venture and Cournot competition, when the market structure is exogenously given. However, it is always less than the marginal social damage.

We then briefly relate our work in this paper to the existing literature.

First consider the case where the market structure is exogenously given. In an n-firm Cournot framework, Katsoulacos and Xepapadeas (1996) show that an increase in emission tax decreases the output level and increases abatement expenses. Moreover, the optimal tax is less than marginal damages. Conrad and Wang (1993) solves for the effects of the emission tax on the output of an oligopolistic industry. In contrast to the above models, Carraro and Soubeyran (1996), Ulph (1996a) and Ulph (1996b), among others, examine the impact of emission taxes when the firms are heterogenous.

Next consider the case where the market structure is endogenous. In a homogeneous product industry with free entry, Katsoulacos and Xepapadeas (1995) show that the optimal emission tax may exceed marginal environmental damages. Clearly, the framework adopted by Katsoulacos and Xepapadeas (1995) is very different from that in our paper. To the best of our knowledge, the present paper is the only one that examines the interaction between environmental policy, market structure, and the level of pollution.

The rest of the paper is organized as follows. In the next section we describe the basic framework. Section 3 contains the positive part of the analysis. The welfare analysis is discussed in section 4. Finally, section 5 concludes.

II. The Model

The market comprises two firms, one multinational (denoted by firm 1) and one domestic (denoted by firm 2), producing a homogenous product.[9]

The market demand function is given by

$$q = a - p, \tag{1}$$

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

There are two factors of production, capital (K) and labour (L). Recall that capital here is a shorthand for all the inputs supplied by the MNC, while labour 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

$$q = (KL)^{\frac{1}{2}}. \tag{2}$$

Let the per unit wage and rental cost for the i-th firm be w^i and r^i (respectively). We assume that the MNC has cheaper access to capital, while the domestic firm has cheaper access to labour. Thus

$$r^1 < r^2 \ \text{ and } \ \mathrm{w}^1 > \mathrm{w}^2. \tag{3}$$

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

$$r^1 = w^2 = c, \quad \text{and } \ \mathrm{r}^2 = \mathrm{w}^1 = \mathrm{b}, \text{where } \ \mathrm{b} > \mathrm{c}. \tag{4}$$

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 we say that the synergistic effect is large. If c is close to b, then we 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 :

$$C_i(q_i) = 2\sqrt{bc}q_i, \ \text{ where } \ \mathrm{i} = 1, 2. \tag{5}$$

We formalise the abatement cost as a linear function of output

$$A^i(q_i) = Aq_i, \tag{6}$$

where A is the abatement cost parameter.[10] This is a linear version of the abatement cost function used by Barrett (1994). For technical reasons we assume that $A < a - 4c$.

We consider a simple two stage game.

Stage 1. The firms sequentially decide whether to opt for Cournot competition, or joint venture formation. There is joint venture formation only if both the forms opt for it.

Stage 2. In case there is Cournot competition, the firms simultaneously decide on their level of output. In case a joint venture forms, the firms simultaneously decide on the level of input to supply to the joint venture, K in case of the MNC and L in case of the domestic firm.

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

Joint Venture. Under a joint venture the MNC supplies capital, and the domestic firm supplies labour, so as to take advantage of synergistic effects. However, because of moral hazard problems, the partner firms cannot write a contract over the amount of labour 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.[11]

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

$$J_1 = \frac{1}{2}(KL)^{\frac{1}{2}}[a - (KL)^{\frac{1}{2}} - A] - cK, \tag{7}$$

$$\text{and } J_2 = \frac{1}{2}(KL)^{\frac{1}{2}}[a - (KL)^{\frac{1}{2}} - A] - cL. \tag{8}$$

Since the input levels under a joint venture are not contractible, we solve for the Nash equilibrium of the game, where the MNC and the domestic firm simultaneously decide on how much capital and labour (respectively) to supply. The reaction functions of the two firms are given by[12]

$$\frac{\partial J_1}{\partial K} = \frac{1}{2}[\frac{a}{2}(\frac{L}{K})^{\frac{1}{2}} - L - \frac{A}{2}(\frac{L}{K})^{\frac{1}{2}}] - c = 0, \tag{9}$$

$$\text{and } \frac{\partial J_2}{\partial L} = \frac{1}{2}[\frac{a}{2}(\frac{K}{L})^{\frac{1}{2}} - K - \frac{A}{2}(\frac{K}{L})^{\frac{1}{2}}] - c = 0. \tag{10}$$

It is easy to see that the equilibrium will be symmetric in the sense that $K = L$.[13] Clearly, given symmetry, the equilibrium is unique. Solving equations (9) and (10) explicitly we find that:

$$\widehat{K} = \widehat{L} = \widehat{q} = \frac{a - A - 4c}{2}, \tag{11}$$

where $\hat{K}$, $\hat{L}$ and $\hat{q}$ denote the equilibrium levels of capital, labour and output respectively.

Letting $\widehat{J}$ denote the equilibrium level of profit for both the firms

$$\widehat{J} = \frac{1}{8}(a - A)(a - A - 4c). \tag{12}$$

Cournot Competition. We then examine the outcome under Cournot competition. Letting P_i denote the profit functions of the two firms under Cournot competition

$$P_i = (a - q_1 - q_2)q_i - 2(bc)^{\frac{1}{2}}q_i - Aq_i, \quad i = 1, 2. \tag{13}$$

Thus the reaction functions are given by[14]

$$\frac{\partial P_i}{\partial q_i} = (a - q_i - q_j) - q_i - 2(bc)^{\frac{1}{2}} - A = 0, \quad i = 1, 2. \tag{14}$$

From equation (14) it is standard to show that in equilibrium $q_1 = q_2$. Letting $\overline{q}_i$ denote the equilibrium output level of the i-th firm

$$\overline{q}_1 = \overline{q}_2 = \overline{q} = \frac{a - A - 2(bc)^{\frac{1}{2}}}{3}. \tag{15}$$

The equilibrium profit level of each Cournot firm

$$\overline{P} = \frac{1}{9}(a - A - 2(bc)^{\frac{1}{2}})^2. \tag{16}$$

From equations (11) and (15) we have the following

Observation. *Under both joint venture and Cournot competition, the equilibrium level of aggregate output, and hence pollution, is decreasing in A.*

III. The Analysis

We begin by comparing the level of pollution under joint venture and Cournot competition. Since the level of pollution 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 (11) and (15), the aggregate output under joint venture exceeds that under Cournot competition only if

$$A > a + 12c - 8(bc)^{\frac{1}{2}} = \widehat{A}. \tag{17}$$

Summarising the above discussion we obtain our first proposition:

Proposition 1. *Cournot competition involves lesser emission compared to that under joint venture formation if and only if $A > \widehat{A}$, i.e. government regulation is strict enough in the sense that A is large enough.*

We then examine whether the firms would prefer to opt for joint venture or Cournot competition. Obviously the firms opt for joint venture provided $\widehat{J} \geq \overline{P}$.[15] Hence from equations (12) and (16) it follows that a joint venture forms provided

$$(a - A)^2 - 4(a - A)[9c - 8(bc)^{\frac{1}{2}}] - 32bc \geq 0. \tag{18}$$

Next, let $Z(A)$ denote the L.H.S. of equation (18). Hence

$$\begin{aligned} Z(A) &= (a - A)^2 - 4(a - A)[9c - 8(bc)^{\frac{1}{2}}] - 32bc, && (19)\\ \text{and } \mathrm{Z}'(\mathrm{A}) &= 2[A - a + 2\{9c - 8(bc)^{\frac{1}{2}})\}]. && (20) \end{aligned}$$

Clearly $Z(A)$ is decreasing in A.[16] Hence there exists some A^* such that equation (18) holds only if $A \leq A^*$. (*See* Figure 1).[17]

Summarising the above discussion we obtain our next proposition:

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

While the welfare analysis will be taken up in the next section, Propositions 1 and 2 allow us to make some preliminary remarks. Let us suppose that environmental degradation is the primary concern of the government. In that case we find that there is no conflict between a socially desirable market structure and the private incentive to sustain a market structure, at least for relatively extreme values of A. When A is high enough, the firms prefer Cournot competition and pollution is also lower under Cournot competition. Similarly, when A is low enough, firms prefer joint venture formation and the level of pollution is also lower under a joint venture.

Let I denote the incentive for joint venture formation, so that $I = \widehat{J} - \overline{P}$. We then decompose the effects of a change in A on I, into three components, the synergistic effect, the moral hazard effect and the rent dissipation effect. This allows us to arrive at the intuition behind the regime switch from joint venture to Cournot competition.

Observe that I can be re-written as follows:

$$I = \widehat{J} - \overline{P} = [\widehat{J} - \frac{M}{2}] + [\frac{M}{2} - \pi] + [\pi - \overline{P}]. \tag{21}$$

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. Thus $\frac{M}{2} = \frac{(a-A-2c)}{8}^2$. Finally π represents the Cournot equilibrium profit of the two firms when they can access both the inputs cheaply. Hence $\pi = \frac{1}{9}(a - A - 2c)^2$.

Consider the first term in square brackets, $[\widehat{J} - \frac{M}{2}]$. Note that $\widehat{J}$ represents joint venture profits when the moral hazard problem is present and M represents joint venture profits when there are no moral hazard problems. Hence this term is a measure of the moral hazard problem. Note that:

$$\widehat{J} - \frac{M}{2} = \frac{1}{8}[(a-A)^2 - 4c(a-A) - (a-A)^2 + 2(a-A)2c - 4c^2] = -\frac{c^2}{2}. \tag{22}$$

Thus the moral hazard effect is independent of A.

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. Observe that

$$\frac{M}{2} - \pi = \frac{1}{8}(a - A - 2c)^2 - \frac{1}{9}(a - A - 2c)^2 = \frac{1}{72}(a - A - 2c)^2. \tag{23}$$

Clearly the rent dissipation effect is decreasing in A.

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. Clearly the synergistic effect :

$$\pi - \overline{P} = \frac{1}{9}[(a - A - 2c)^2 - (a - A - 2\sqrt{bc})^2 = \frac{4}{9}(\sqrt{bc} - c)(a - A - c - \sqrt{bc}). \tag{24}$$

So the synergistic effect is also decreasing in A.

Note that a joint venture forms if, and only if the second and the third effects outweigh the first. Moreover, observe 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.

We then identify the parameter configurations under which a regime switch is more likely. Observe that from equation (18) one can write that

$$A^* = a - 2(9c - 8\sqrt{bc}) \pm 2\sqrt{81c^2 - 144c\sqrt{bc} + 72bc}. \tag{25}$$

We can use the fact that $Z'(A) < 0$ to argue that the square root term must take the negative sign.[18]

Next comparing $\widehat{A}$ and A^*, we find that $\widehat{A} \geq A^*$, if and only if

$$15c - 12\sqrt{bc} \geq -\sqrt{81c^2 - 144c\sqrt{bc} + 72bc}. \tag{26}$$

There are two cases to consider.

Case 1. $25c \geq 16b$, i.e. $15c - 12\sqrt{bc} \geq 0$. Hence, in equation (26), the right hand side is strictly negative, while the left hand side is positive. This in turn implies that $\widehat{A} \geq A^*$.

Case 2. $25c < 16b$ i.e. $15c - 12\sqrt{bc} < 0$. Hence, in equation (26), the left hand side is strictly negative. Therefore, $\widehat{A} \geq A^*$, if and only if

$$11c + 18b \geq 54\sqrt{bc}. \tag{27}$$

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

We then turn to the central problem of this section, i.e. to 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. $\widehat{A} > A^*$.

Note that for $A \leq A^*$, the firms opt for joint venture formation, whereas for $A^* < A < \widehat{A}$, the outcome involves Cournot competition (*see* Proposition 2). Moreover, at A^*, the level of pollution is greater under Cournot competition (since $\widehat{A} > A^*$). Thus the level of pollution is monotonically declining in A (*see* Proposition 1), except for an upward jump at $A = A^*$. (*See* Figure 2).

Case 2. $\widehat{A} < A^*$.

Note that at A^*, the level of pollution is lower under joint venture (since $\widehat{A} < A^*$). Thus the level of pollution is monotonically declining in A (*see* Proposition 1), except for a downward jump at $A = A^*$. (*See* Figure 3).[19]

Summarising the above discussion we obtain

Proposition 3. *(i) For $\widehat{A} > A^*$, the relation between the abatement cost A and the level of pollution is non-monotonic. In fact, the level of pollution is monotonically declining in A, except for an upward jump at $A = A^*$.*

(ii) For $\widehat{A} < A^*$, the level of pollution is monotonically decreasing in A, with a downward jump at $A = A^*$.

Note that Proposition 3(i) 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 depends on the fact that the market structure is *endogenous*. As A increases from $A^* - \epsilon$, to $A^* + \epsilon$, there is a regime switch from joint venture to Cournot competition (*see* Figure 2). Thus the level of output and hence pollution goes up as the market structure becomes more competitive. Hence as governmental policy becomes more strict, the level of pollution may, in fact, increase.

IV. The Optimal Abatement Tax

We first solve for the first best outcome. This exercise is carried out under two premises. First, the government can dictate which market structure to follow. Second, the government can dictate the input level of each firm.

The solution is divided into two parts. We first solve for the first best outcome when the market structure is exogenously given. We 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

$$D(q_1 + q_2) = \mu(q_1 + q_2)^2, \tag{28}$$

where μ denotes the social damage parameter. Thus, for a given level of output, greater is μ, greater is the social damage.

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

Cournot Competition: We assume that the 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. While calculating the producers' surplus, we assume that the whole of the MNC profit is re-invested in the domestic country (or is paid out to the (domestic) workers as bonus, etc.). Thus the producers' surplus includes the profit of both the firms.[20] Hence welfare under Cournot competition

$$W_{CC} = (a - q_1 - q_2 - 2\sqrt{bc})(q_1 + q_2) + \frac{(q_1 + q_2)^2}{2} - \mu(q_1 + q_2)^2. \tag{29}$$

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 is given by

$$\frac{\partial W_{CC}}{\partial q_i} = a - q_1 - q_2 - 2\sqrt{bc} - 2\mu(q_1 + q_2) = 0, \ i = 1, 2. \tag{30}$$

From equation (30), it is clear that the outcome is symmetric. Hence we have that the optimal level of per firm output under Cournot competition, q_C, satisfies

$$q_C = \frac{a - 2\sqrt{bc}}{2(1 + 2\mu)}. \tag{31}$$

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

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

$$W_{JV} = (a - \sqrt{KL})\sqrt{KL} - cK - cL + \frac{KL}{2} - \mu KL. \tag{32}$$

The first order condition for the optimal level of output under a joint venture is given by

$$\begin{aligned}
\frac{\partial W_{JV}}{\partial K} &= \frac{1}{2}(a - \sqrt{KL})\sqrt{\frac{L}{K}} - \frac{1}{2}\sqrt{\frac{L}{K}}\sqrt{KL} - c - \frac{L}{2} - \mu L = 0, \\
\frac{\partial W_{JV}}{\partial L} &= \frac{1}{2}(a - \sqrt{KL})\sqrt{\frac{K}{L}} - \frac{1}{2}\sqrt{\frac{K}{L}}\sqrt{KL} - c - \frac{K}{2} - \mu K = 0.
\end{aligned}$$

It is straightforward to see, mimicing the argument in footnote 11, that the outcome is symmetric. Hence the optimal outcome solves

$$q_J = K = L = \frac{a - 2c}{1 + 2\mu}. \tag{33}$$

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.[21]

We can summarize the above discussion to obtain our next proposition.

Proposition 4. *(i) Under Cournot competition the first best level of output involves* $\frac{a-2\sqrt{bc}}{1+2\mu}$.

(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 μ.

(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 the first best involves joint venture formation.

We then examine if the first best outcome characterised above can be implemented when the government cannot directly implement either the market structure or the level of output, but can only use the level of A as a policy tool.

We 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.

We then solve for A_J and A_C. Let us 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 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

$$A_J = \frac{a(2\mu - 1) - 8\mu c}{2\mu + 1}. \tag{34}$$

Clearly, $\frac{\partial A_J}{\partial \mu} = \frac{4(a-2c)}{(1+2\mu)^2} > 0$.

We then solve for A_C. Recall that under Cournot competition the equilibrium level of output for both the firms is given by $\frac{a-A-2\sqrt{bc}}{3}$. Thus A_C solves the equation $\frac{a-A-2\sqrt{bc}}{3} = \frac{a-2\sqrt{bc}}{2(1+2\mu)}$. Hence we have that

$$A_C = \frac{(4\mu - 1)(a - 2\sqrt{bc})}{2(1 + 2\mu)}. \tag{35}$$

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

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

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 we 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 abatement tax 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 internalisation 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 5. *(i) Both A_J and A_C are increasing in μ.*

(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, $\frac{2\mu(a-2c)}{1+2\mu}$.

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

The intuition for Proposition 5(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.

Having solved for the first best outcome, we 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, just through manipulating A, ensure that the market structure and the level of output is optimal?

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.

Summarising the above discussion, we obtain our final proposition.

Proposition 6. *The first best outcome can be implemented if and only if $A_J \leq A^*$. In that case the optimal policy involves setting $A = A_J$.*

Recall that A_J is increasing in μ. Hence implementing the first best outcome is possible provided μ is small, not otherwise.

As Proposition 6 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?

We then 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. We 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 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 5.)

Interestingly, we find that even the second best level of abatement tax is less than the marginal social damage. In fact, in Case 2(b), the optimal abatement tax is even less than A_C, and is different from the optimal tax under both joint venture and Cournot competition.

V. Conclusion

This paper examines the impact of environmental policy in a duopoly framework where the firms endogenously decide whether to form a joint venture, or opt for Cournot competition. We find that several conclusions of interest emerge.

Our analysis shows that the pollution level depends on both government regulation and market structure. Apart from its direct effect on the pollution level, environmental regulation may affect the level of pollution indirectly, via the market structure. We find that if the synergistic effect is large, then stricter governmental regulations could lead to a regime switch from joint venture to Cournot competition, thus causing the level of pollution to increase. This result suggests that the issue of market structure needs to be carefully addressed while analysing environmental policy.

We also derive some interesting welfare results. We find that if the industry is not too polluting, then the first best outcome (which involves joint formation) can be implemented through manipulating the level of abatement taxes alone. In case the industry is polluting, the second best level of abatement tax may or may not equal the optimal tax under either joint venture or Cournot competition. Moreover, for a given market structure, the optimal tax is less than the marginal social damage.

Finally, we briefly discuss some robustness issues.

First, in our framework the alternative to joint venture formation involves quantity competition. This immediately raises the question as to whether our results go through if, instead, the firms compete over prices. Fortunately our analysis, not reported here, shows that they do.

Second, note that the profit-sharing rule in a joint venture is taken to be exogenously given (and symmetric). However, given the symmetry of our model, most formulations that allow the profit-sharing rule to be endogenously determined should lead to a symmetric rule.

Third, in this paper we assume that the firms are symmetric. Again, our analysis, not reported here, shows that very similar results go through even if we assume that the firms are asymmetric, in the sense that $w_1 \neq r_2$ and $w_2 \neq r_1$, or if the abatement technology is different for the two firms.

Fourth, in this paper we assume that the technology is exogenously given, so that a change in the emission tax leads to changes in output levels, rather than the emissions technology. An alternative formulation would be to consider the case where changes in the emission tax lead to changes in the technology, as well. However, our results go through as long as changing the existing technology is relatively costly.

Finally, while our analysis does use explicit functional forms, we believe that the use of functional forms is not critical. Given the strong intuitive content of most of the results, most of these should go through in a more general framework.

Endnotes

1. For example, Hergert and Morris (1998) mention that the number of US-EEC joint ventures increased from less than 10 in 1979, to more than 190 in 1985. Since then the rate of joint venture formation has, in fact, increased dramatically. *See* Hergert and Morris (1998) and Pekar and Allio (1994) for surveys of this phenomenon.

2. *See*, among others, Baumol and Oates (1998).

3. *See*, for example, Buchanan (1969).

4. *See*, among others, Carraro and Soubeyran (1996), Conrad and Wang (1993) and Katsoulacos and Xepapadeas (1996).

5. *See* Miller et al. (1996).

6. Here capital (respectively labour) is a shorthand for all factors of production which the MNC (respectively the domestic firm) can access relatively cheaply.

7. 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. *See*, Carraro and Siniscalco (1994).

8. This replicates the result obtained by Buchanan (1969) in case of monopoly, and by Katsoulacos and Xepapadeas (1996) in case of oligopoly.

9. The basic model draws on Roy Chowdhury and Roy Chowdhury (2001). Roy Chowdhury and Roy Chowdhury (2001) is, of course, concerned with the theory of joint venture life-cycles in a non-polluting industry.

10. We can think of this as an emission tax. Suppose that the level of emission is a linear function of output $E = pq_i$. Let the emission tax take the form of $\alpha E = \alpha p q_i$. For $A = \alpha p$ we obtain equation (6).

11. Alternatively, one can assume that there is no moral hazard problem, but that joint venture formation involves some exogenous cost, e.g. cost of having a joint venture headquarter, etc. This does not affect our results qualitatively.

12. It is straightforward to see that

$$\frac{\partial^2 J_1}{\partial K^2} = -\frac{L^{\frac{1}{2}} K^{-\frac{3}{2}} (a - A)}{8} < 0.$$

The argument for firm 2 is symmetric.

13. Suppose to the contrary there is a non-symmetric equilibrium $(\overline{L}, \overline{K})$. Without loss of generality, let $\overline{L} > \overline{K}$. From equation (9), $\frac{\overline{L}}{2}[\frac{a-A}{2(\overline{LK})^{\frac{1}{2}}} - 1] - c = 0$. Since $\overline{L} > \overline{K}$, it follows that $\frac{\overline{K}}{2}[\frac{a-A}{2\overline{q}} - 1] - c < 0$. This, however, violates equation (10).

14. It is straightforward to see that $\frac{\partial^2 P_i}{\partial q_i^2} < 0$.

15. We thus adopt the tie-breaking rule that in case of indifference the firms prefer to opt for joint venture formation. One can, however, adopt a different tie-breaking rule without affecting the analysis in any significant way.

16. Clearly, $Z'(A) < 0$, if and only if $A < a - 2c + 16[(bc)^{\frac{1}{2}} - c]$. Because of synergy $b > c$, so that $(bc)^{\frac{1}{2}} - c > 0$. Moreover, since the joint venture output is positive we have that $A < a - 4c$. Hence $A < a - 4c < a - 2c + 16[(bc)^{\frac{1}{2}} - c]$. Thus $Z'(A) < 0$.

17. We provide an example to show that the various conditions required for our analysis are consistent. Let $a = 13c$, $b = 9c$ and $A = 2c$. For these parameter values observe that $a - A - 4c > 0$, $a - A - 2(bc)^{1/2} > 0$, $\hat{A} = c > 0$ and $Z(A) > 0$.

18. From equation (20), $A - a + 2(9c - 8\sqrt{bc}) < 0$. Therefore, $a - 2(9c - 8\sqrt{bc}) > A^*$. Hence the result.

19. It is clear that for $\widehat{A} = A^*$ the level of pollution is continuously decreasing in A.

20. Of course, if the MNC repatriates its profit to its home country, then the producers' surplus would only include the profit of the domestic firm. Depending on the context, either of these assumptions could be the relevant one. For simplicity, we choose to focus on the first one.

21. Note that, *for the same level of output*, the welfare level under joint venture formation is 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, because of synergy, the aggregate profit under a joint venture is greater. Hence, the *maximal* level of welfare under a joint venture exceeds that under Cournot competition.

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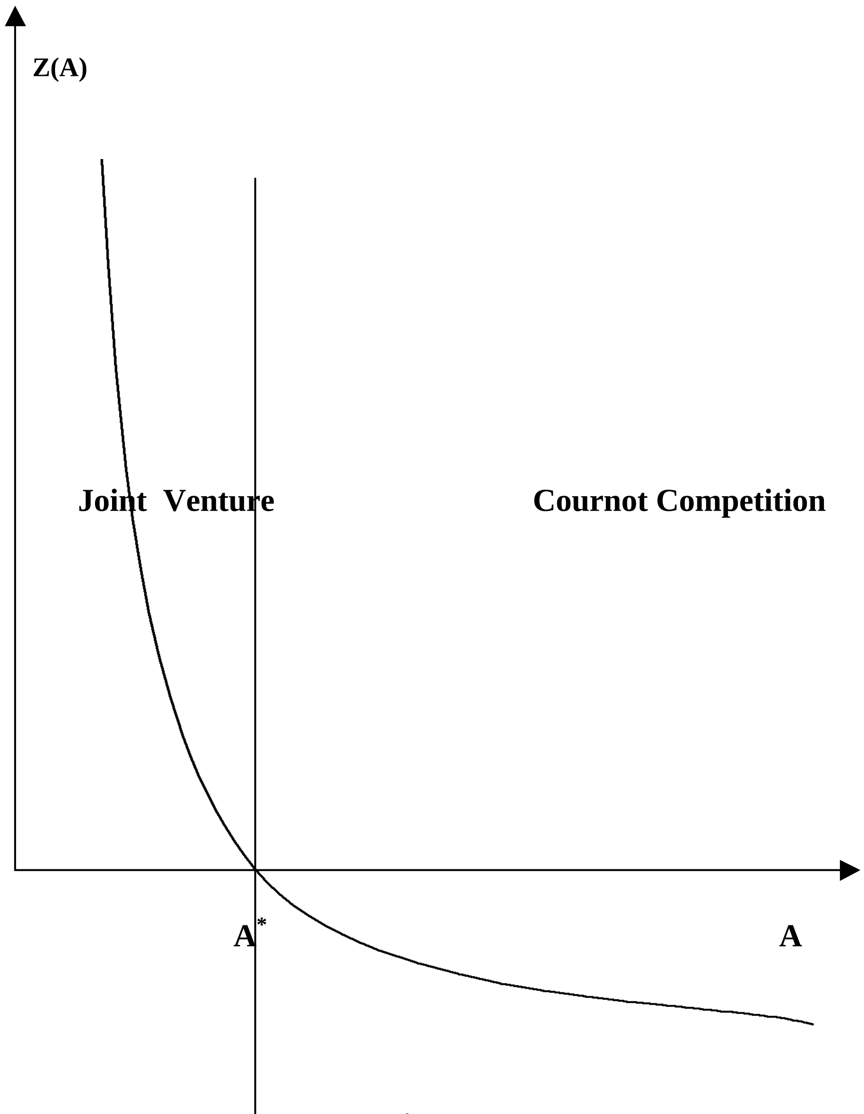

Figure 1

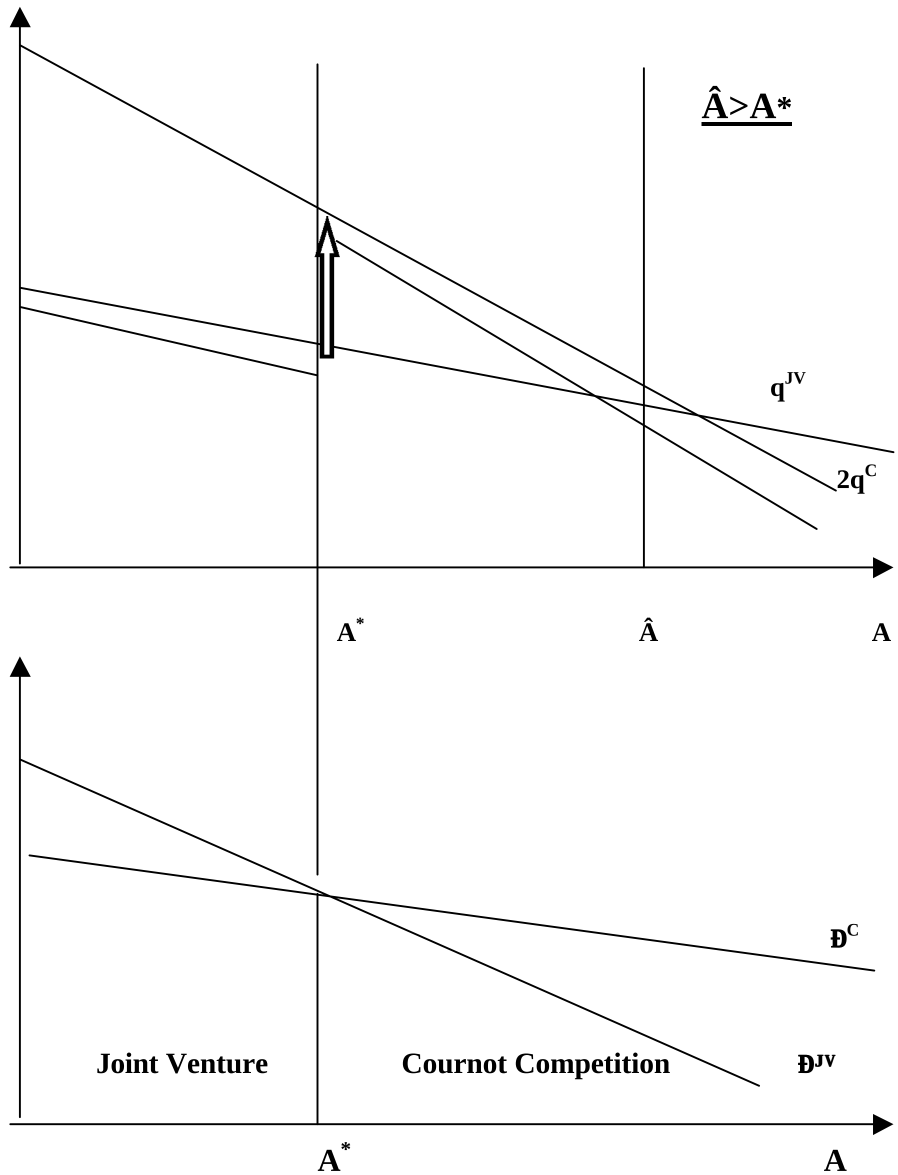

Figure 2: Discrete Upward Jump in Pollution

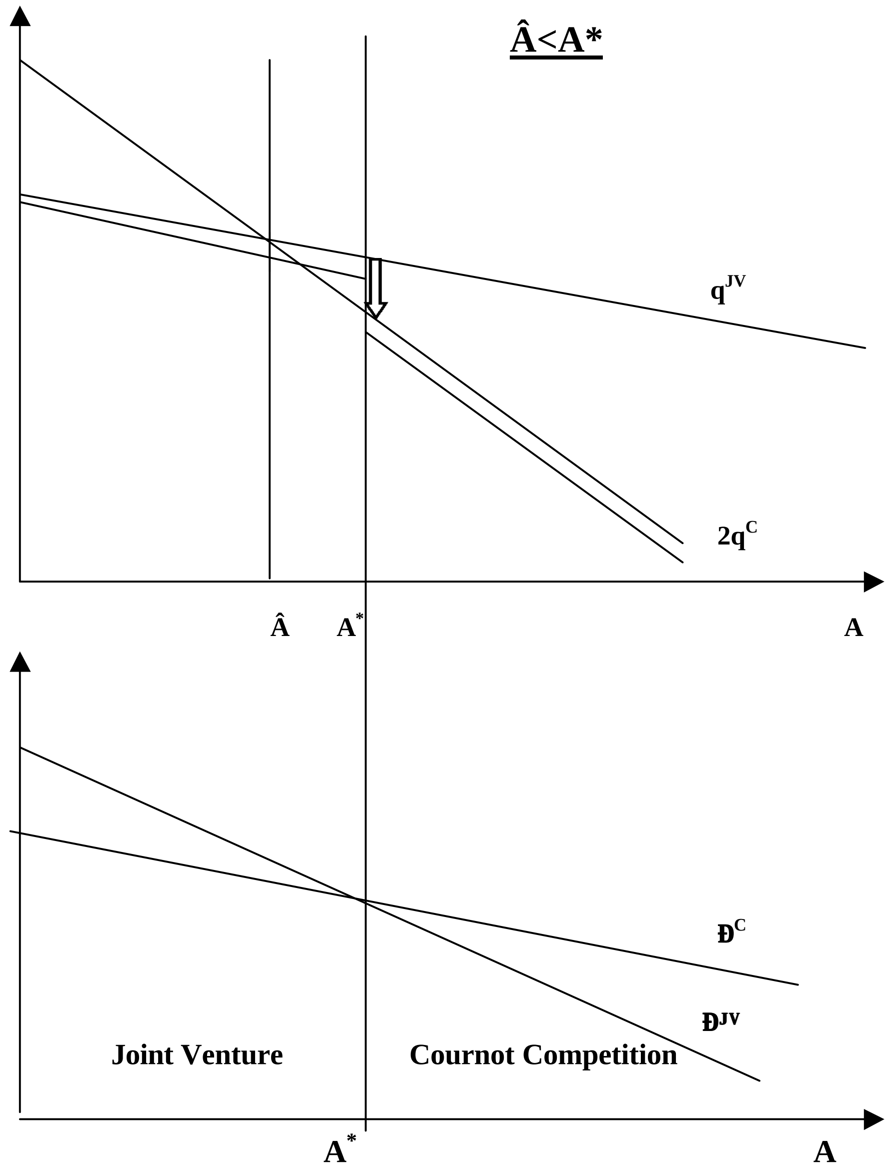

Figure 3: Discrete Downward Jump in Pollution

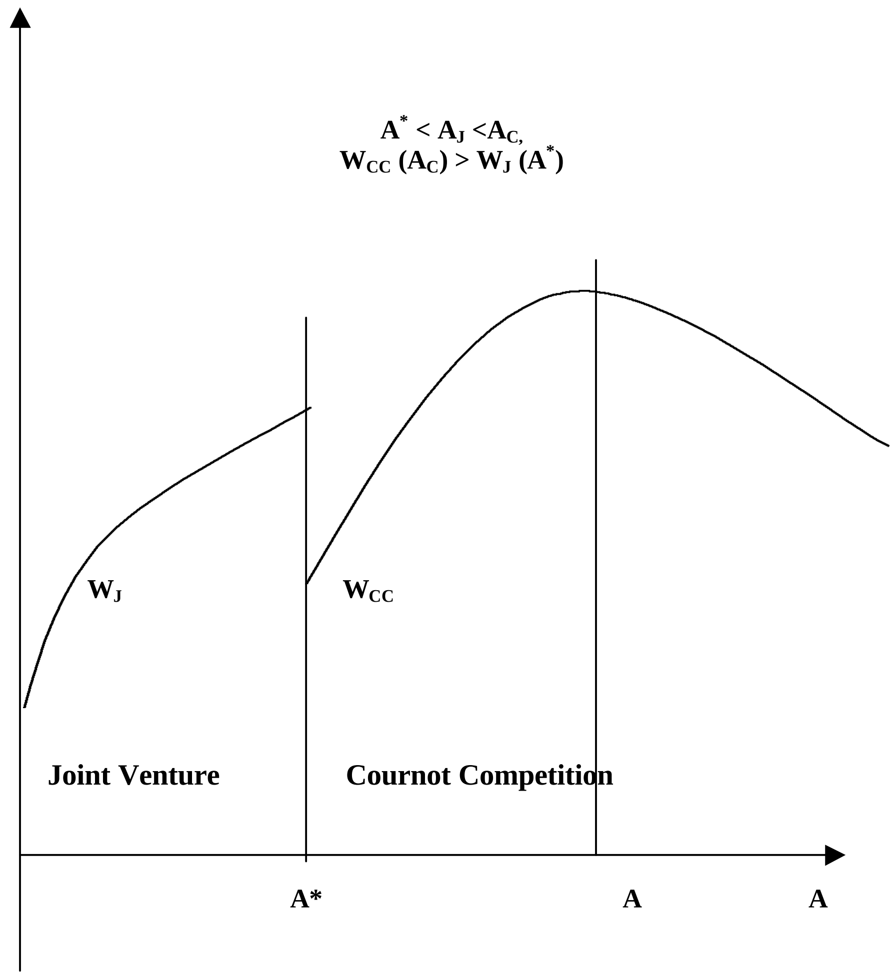

Figure 4: Second-Best Outcome

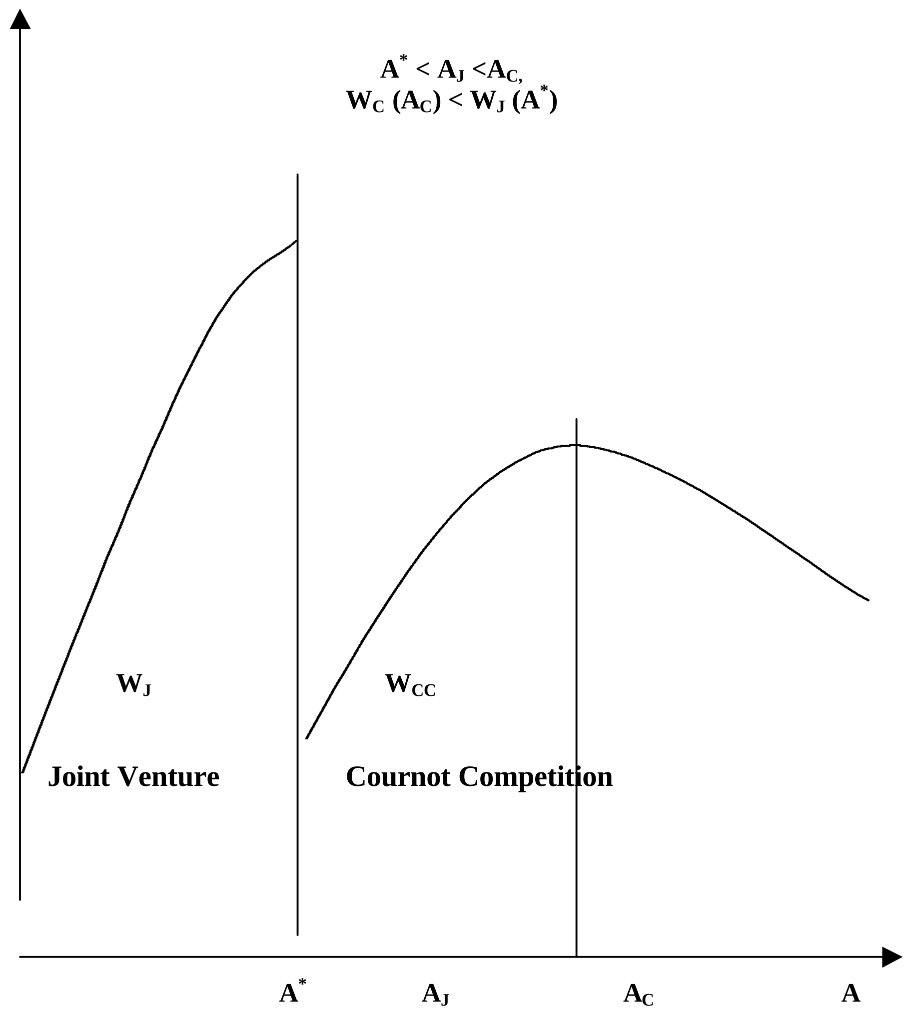

Figure 5: Second Based Outcome