Joint Ownership and Interconnection Pricing in Network Industries

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ABSTRACT

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In this thesis, we consider a market situation where competitive downstream firms jointly own a monopolistic upstream firm and determine a common interconnection price by bargaining process (Joint Ownership). Using a simple game-theoretic model, we show that the performance of joint ownership is crucially dependent upon how equity shares are initially allocated and which bargaining rules are employed.

In short, joint ownership has two countervailing effects in terms of social welfare. On one hand, it undoubtedly increases welfare compared to the separate ownership, where a separate entity exists for upstream operation, by eliminating the welfare loss from 'double marginalization.' On the other hand, it might induce the firms who may well prefer upstream pie-splitting to downstream competition, to have the incentives of tacit collusion to the detriment of consumers. The net effect can be determined only after actual equity shares and bargaining rules are specified.

We show that to enhance the performance of joint ownership, it is necessary to make the equity shares asymmetric and to allow more bargaining power to the low share firm. Also, we argue that blind push to downstream competition may be harmful to social welfare by increasing the possibility of tacit collusion, unless equity shares and bargaining powers are accordingly adjusted. The analysis is extended to allow for the case of regional monopolists with respective captive markets and of competing firms with asymmetric downstream costs. A few implications in implementing joint ownership in practice will follow.

Table of Contents

Chapter 1

Introduction

1.1 Background and motivation

With the introduction of privatization and deregulation in the network industries worldwide since 1980s, various ownership structures have emerged as alternative policy options about vertical market structure.[1] The reason why new vertical market structures were required stems from the fact that technological advances in the downstream operation of network industries (e.g. in telecommunications industry, dramatic decline in the costs associated with the provision of long-distance services, such as switching and trunking) makes naturally monopolistic and potentially competitive markets coexist vertically. Accordingly, how to design the ownership and governance structures in both upstream and downstream markets and how to link these markets vertically turned out to be a critical point in successful performance of network industries. Alternatives for vertical market

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[1] By 'network industry,' we mean an industry which is highly capital-intensive in building and maintaining its vital network, hence, exhibits significant economies of scale in some or all of its operations. Traditionally, it includes telecommunications, electricity, gas, water/sewerage, post, railway industries, etc.

structures include (i) integrated monopoly; (ii) structural separation; (iii) vertical integration; (iv) accounting separation; and (v) joint ownership (Armstrong and Doyle, 1995).

In the UK, for instance, gas and water/sewerage industries remained as integrated monopolies, while in the electricity and railway industries, structural separation has been introduced.[2] Vertical integration (or more precisely, accounting separation) was adopted in the telecommunications industry. Finally, joint ownership is observed in the relationship between transmission and distribution operation in the electricity industry.[3]

Thus far, there has been a considerable amount of research on alternative (i) mainly from the regulatory perspective, and on (ii), (iii) and (iv) mostly in the context of telecommunications industry. However, alternative (v) has been given relatively little attention as a possible vertical market structure. This thesis attempts to explore the welfare implications of and possible problems from joint ownership.

Generally speaking, joint ownership in network industries is the ownership structure in which multiple firms operating in (potentially) competitive downstream sector jointly own a monopolistic firm operating in naturally monopolistic upstream sector. For example, the 1988 White Paper of the UK government suggests joint ownership of a monopolistic electricity transmission company (NGC: National Grid Company) by twelve distribution companies

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[2] The US telecommunications industry has also been characterized by structural separation, after breaking-up AT&T and before passing the new Telecommunications Act 1996, which enables RBOCs to enter into inter-LATA long-distance markets.

[3] For the detailed history of privatization and deregulation in the UK network industries, see, among others, Vickers and Yarrow (1988) and Armstrong et al. (1994).

(RECs: Regional Electricity Companies), after generation and transmission operation of the former CEGB were vertically separated (Department of Energy, 1988). Behind this lie several rationales ranging from the economies of scale in electricity transmission to the salability in the process of privatization.[4] Also, joint ownership is observed in many oil pipeline industries (Hillman, 1991). Even without the government intervention during the process of privatization, joint ownership can emerge from the natural market forces. That is, in many financial service networks in the US, ownership of the network switch is shared jointly by a large number of the members of the network (McAndrews and Rob, 1995).

Of course, we are not saying that joint ownership is a unique solution to the problem of vertical market structures after introducing competition in potentially competitive market. Indeed, to answer the question of which structure would be most suitable for a network industry requires formidable task, evaluating relative strengths and weaknesses in a variety of perspectives. In many instances, vertically integrated structure, under which an upstream monopolist who owns a bottleneck facility compete with downstream rivals who need an access to this facility, can be a more promising alternative, especially in pursuit of vertical economies of scope. However, as observed in the experiences of the UK gas and telecommunications industries, there appears to be a serious drawback in vertically integrated structure, surrounding the setting of access terms and conditions including the level and structure of access price.

In the first place, access pricing has been a continuous battleground between the incumbent and entrants, due to the anti-competitive incentives of the incumbent *to raise rival's costs*. Second, various public utility pricing practices,

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[4] Private investors were more likely to be willing to buy the grid if it was bundled with other assets, namely, RECs (see Armstrong et al., 1994).

such as the universal service and geographically uniform tariffs, make the agreement on the level and structure of access price unattainable. Third, from the perspective of regulation, to derive the optimal access price imposes a major informational and computational burden upon the regulator.

After all, when the social cost associated with the problem of access pricing is considerable, vertical separation or joint ownership can be considered as alternatives to vertical integration. Vertical separation, however, is not free from its own drawback of missing the gains from vertical economies of scope. Also, it can be readily expected that the problem of double marginalization will be prevalent if downstream market is not perfectly competitive. In this case, the argument for joint ownership as another alternative structure can be justified. In short, joint ownership can be understood as a compromise between the needs to preserve vertical economies of scope, to eliminate the problem of double marginalization and to avoid the access pricing problem. As will be seen later, however, joint ownership itself has its own merits and drawbacks compared to the other structures.

This thesis examines the welfare implications of joint ownership structure using a simple game-theoretic model, to provide rooms for more systematic and comprehensive comparison among the alternative vertical structures. Specifically, we have in mind a situation in which multiple downstream firms jointly own single upstream firm with different equity shares. Ownership here accompanies rights of control, and as such, downstream firms influence on the decision process for the common interconnection price in a variety of ways.[5] We suppose that the

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[5] By the 'interconnection price,' we mean a general wholesale price of an input from the upstream to downstream firm. In the context of network industries, it is also referred as the access price, or access charge.

actual interconnection price is an outcome of the associated bargaining process among the downstream firms and analyze the effects of some alternative bargaining rules on the interconnection price, firms' profits and social welfare. Also we capture the effect of downstream competition using a conjectural variation model.

In doing so, of particular importance is the possible conflicts of interest among the downstream firms with asymmetric equity shares, in choosing common interconnection price. Comparing joint ownership with vertical separation, special attention will be paid to the trade-off when one moves from the latter to the former: On one hand, joint ownership eliminates (or mitigates at least) the welfare losses of double marginalization; One the other hand, it can be used as a device for tacit collusion among the downstream competitive firms. Together, these two determine the net performance of joint ownership.

1.2 Literature review

Traditionally, the issue of interconnection pricing has been mainly discussed in the context of vertical integration, and there has been a growing amount of research in this context.[6] This is due to the possible anticompetitive effects for the incumbent of setting the access price to foreclose the rival or to squeeze vertically. As already noted, however, we are mostly concerned with joint ownership structure and possible problems arising from the setting of interconnection price. There have been few attempts specifically focused on the interconnection pricing

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[6] See, among others, Armstrong and Doyle (1994, 1995), Armstrong (1996), Armstrong et al. (1996), Cave and Doyle (1994), Economides and Salop (1992) and Hart and Tirole (1990). Also see Laffont and Tirole (1994a) and Laffont et al. (1996a, 1996b).

in joint ownership and the closest ones are Flath (1989) and McAndrews and Rob (1995).

Flath (1989) shows that in a general vertical setting where multiple firms operate both in upstream and downstream markets, vertically related Cournot oligopolies trading at arms' length can produce less output when downstream firms own equity shares in upstream firms. At first glance, this situation resembles the joint ownership structure. However, the result obtained in Flath (1989) cannot be directly employed for our purposes since the characterizing feature of network industries must be the co-existence of upstream monopoly and downstream competition. Also, this result flaws from the underlying assumption of 'silent financial interests' in which stockholding does not enable any downstream firms to control the interconnection price of an upstream firm.[7]

McAndrews and Rob (1995) deals with the problem of joint ownership directly in the context of network industries. Having observed joint ownership of ATM networks in the US, they analyze the adoption decision (which network a bank chooses to join) and subsequent pricing of switch and ATM services. The essence of their model is to compare the degree of concentration and the level of retail price, under two solely owned switches vs. one solely owned and one jointly owned switch. They show that the upstream industry is more concentrated under one joint ownership switch and that the resulting retail price becomes more monopolistic. In doing so, they simply assume that the interconnection price is determined to maximize joint profit of the member firms, thus, neglect the possibility that asymmetric equity shares and various bargaining rules can

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[7] For various control arrangements arising from the stockholding, see Bresnahan and Salop (1986). They analyze a number of alternative control arrangements within a standard non-cooperative oligopoly model, in dealing with the production joint ventures between competing firms.

influence the resulting interconnection price.

Recently, in a comprehensive review of the issues associated with access pricing problems, Armstrong and Doyle (1995) mentions briefly and intuitively about joint ownership structure as follows:

> Without regulation, the way access prices are set by the jointly owned firm depends on the arrangements governing the management of the firm. One extreme case is where a single competitive firm has a majority stake in the bottleneck firm and hence can control its charging policy. . . . The other extreme case is where all competitive firms are symmetric, where they all own equal shares of the bottleneck firm, and where the management of the bottleneck firm sets the access charge in order to maximize the total profits of its parent companies. . . . The way this would be done in most cases would be to set a high access charge . . . . with the result that firms receive the bulk of their profits from their shares in the bottleneck firm. Again, it seems unlikely that access charge regulation can safely be abandoned. . . . In sum, there seems to us to be no good reason to think that joint ownership in itself is a good solution to the access pricing problem. (p. 10)

In a sense, our research is an extension of Armstrong and Doyle (1995), largely in two respects. First, we allow for the possibility of asymmetric equity shares, which may well make the interests of the firms diverge to the benefit of a society. Indeed, as will be seen clearly later in the thesis, tacit collusion which harms the consumers, arises only when the firms' interests are nearly coincident. Second, we suppose that the interconnection price is an outcome of an associated bargaining process rather than of the joint profit maximization. We argue that explicit bargaining situation is more appropriate to represent the internal process of the setting of interconnection price, whereas joint profit maximization hardly makes sense in the absence of any arrangement for side payment. In other words, there is no reason to believe that the firms would agree to the level of interconnection price which maximizes their combined profits.

Finally, in a somewhat different context of the two-way access pricing problem,[8] Armstrong (1996) asserts that "the setting of high access charges can act as an instrument of collusion, the reason being that high charges increase the cost of reducing prices unilaterally . . . . which thereby induces collusion." (p. 15). From this insight, he concludes that

> A major contrast between one-way and two-way models of access is that in the former the chief danger is that high access charges could be used to anti-competitive effect - perhaps to drive out competitors in the downstream market - whereas in the latter case high access charges may be used as an instrument of collusion. (p. 15)

Later in this thesis, we argue that one of the most serious problem of joint ownership is the possibility of tacit collusion in the setting of common interconnection price. Therefore, the intuitions obtained in the two-way access pricing situation by Armstrong is expected to be used helpfully in examining the welfare consequences of joint ownership.

1.3 Structure and scope of the study

This thesis focuses on the welfare implications of joint ownership as an alternative vertical market structure in network industries. For this, we first implicitly assume that the ownership of a network industry is already in the private hands, hence, the

[8] Here, 'two-way access' implies a situation in which several firms need to purchase vital inputs from each other to provide a comprehensive service.

transfer of ownership from public to private hands - that is, privatization itself - is not our concern. Next, we avoid the fundamental question of what drives different vertical market structures. In fact, the choice of a certain ownership structure is an outcome of various inter-related considerations, including pure economic performance, demand and supply characteristics of the industry in question, other political and institutional performances, etc. We here restrict our attention to the pure economics viewpoint in evaluating relative performance of joint ownership. Finally, mainly for analytical tractability, we do not consider explicitly the equity share trading stage of the game and simply suppose that the initial allocation of the equity share is exogenously given, possibly by the regulating authorities.

Comparing joint ownership with vertical separation, we make several policy recommendations in moving from the latter (or from the integrated monopoly) to the former market structure. Once the possible dangers of joint ownership have been identified, we will explore how to escape from these dangers, in terms of the allocation of initial equity shares and adjustment of relative bargaining powers.

The organization of the thesis is as follows. In Chapter 2, we briefly examine the joint ownership structures in practice, which include joint ownership in the UK electricity market and in the US ATM market. In Chapter 3, we setup the basic model of joint ownership and derive the equilibrium outcomes, to show that the welfare effect of joint ownership is heavily dependent on the relative equity shares and associated bargaining rules. We also compare the equilibrium outcomes of vertical separation with that of joint ownership under several bargaining scenarios and show that joint ownership undoubtedly increases social welfare relative to the separate ownership.

Chapter 4 extends the basic model to the case of regional monopolies with respective captive markets and to the case of asymmetric firms in terms of downstream retailing costs, to provide more realistic welfare consequences. In

Chapter 5, we will discuss a variety of policy implications associated with implementing joint ownership in practice. These would include optimal design of alternative bargaining rules, allocation of the initial equity shares to satisfy the participating constraints, interconnection price regulation when the upstream marginal cost cannot be readily observed, and the possibility of welfare losses originating from managerial and institutional conflicts.

Finally, Chapter 6 concludes the paper with acknowledging limitations of this research and identifying further research directions.

Chapter 2

Joint Ownership in Practice

In this Chapter, we will examine briefly the examples of joint ownership structure in practice. These include joint ownership in the UK electricity market (more precisely, between transmission and distribution of electricity) and joint ownership in the US financial markets (in particular, in the US regional ATM market).

2.1 Joint ownership in the UK electricity market

The 1988 White Paper of the UK government presented by the Secretary of State for Energy contains many revolutionary measures for privatizing the electricity supply industry in England and Wales.[1] Among these are: (i) vertical separation between generation and transmission; (ii) horizontal breakup and liberalization of generation; (iii) a regional structure for distribution and retail supply; and (iv)

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[1] Prior to the privatization in England and Wales, the CEGB (Central Electricity Generating Board) was responsible for generation and transmission, and the 12 regional Electricity Area Boards for distribution and supply of electricity.

phased liberalization of retail supply (Armstrong et al., 1994).

In suggesting these structural policy directions, it was strongly asserted that two key features of the pre-1988 structure would be retained in the privatized industry. These are

1. *The regional nature of the Area Boards, responsible for the distribution of electricity to the final customer.* The reason for this decision was explained as follows: "There is a strong case for retaining independent regional distribution companies, to respond to local needs and prospects. It is important for both customers and employees that the companies responsible for distributing electricity should be concerned with particular areas and should develop a regional identity." (Department of Energy, 1988, p. 3).

2. *The national Grid and the benefits it provides.* This is to maintain the major advantages of a national integrated system with a merit order of operation and high reliability. Following this judgment, the twelve Area Boards was privatized as twelve distribution companies (now called RECs: Regional Electricity Companies) and each was given the statutory obligation to supply its area. More importantly, the RECs have come to jointly own the grid (NGC: National Grid Company) as the White Paper puts it:

> Control and ownership of the National Grid will be transferred to the distribution companies. This is because the grid has to retain a central role in planning and directing the use of power stations to minimize cost and to ensure that the system does not fail. It follows from this that, if the CEGB or any other generating company owned the grid, it would inevitably have to direct the use of all the major power stations on the system. To a large extent, it would have to determine how much competing generation was allowed

> allowed access to the system and how its competitors' stations were run. The government does not believe that it would be fair to put any generating company in such a position after privatization, where it effectively owns the means of transmission and controls its competitors' power stations. This task will therefore be given to a grid company owned jointly by all the distribution companies, which will have a direct incentive to seek the cheapest sources of supply and to promote competition among generators. (pp. 6-7)

In addition to this, it was believed that, under joint ownership, potential private sector generators would be provided with confidence on the fair treatment in connecting to the system. They would not face the prospect of having their power stations directed by grid controllers working for the CEGB.

With regard to the allocation of equity shares in the NGC, the procedure was mainly dominated by other than the economic principles. That is, equity shares in the NGC were allocated as a sort of "gift" from the Secretary of State for Energy to the RECs. Table 2.1 below shows the relative amounts of equity shares bestowed to each REC, which were determined "broadly in proportion to the CCA net assets of each REC as at 31/3/89, and adjusted so that the minimum holding is 5.4%." (Thomson, 1993).

2.2 Joint ownership in the US ATM market

Even without the government intervention during the process of privatization, joint ownership can emerge from the natural market forces. McAndrews and Rob (1985) observe that in many financial service networks in the US, ownership of the "network switch," that is, the central device that acts as a routing, coordinating, and communicating agent to the network's members (or nodes), is shared jointly

Table 2.1 Equity share holdings of the RECs in the NGC

	Shares issued (million)	NGC holding (£ million)	NGC holding (%)
Eastern Electricity	269.9	146.6	12.5
East Midlands Electricity	218.1	98.5	8.4
London Electricity	218.1	123.1	10.5
MANWEB	118.7	64.5	5.5
Midlands Electricity	209.4	107.9	9.2
Northern Electric	123.1	76.2	6.5
NORWEB	172.7	96.2	8.2
SEEBOARD	127.4	85.6	7.3
Southern Electric	269.9	129.0	11.0
South Wales Electricity	101.5	63.3	5.4
South Western Electricity	123.1	73.9	6.3
Yorkshire Electricity	207.3	107.8	9.2
Total	2159.2	1172.6	100.0

Source Thomson (1993)

by a large number of the members of the network. As they put it:

> Notably, 3 of the 10 largest regional shared automated teller machine (ATM) networks in the United States are operated essentially as cooperatives, while several of the remaining ones are owned by a group that generates the lion's share of the network's activity. The two largest securities depositories and settlement networks, Depository Trust Company and the Participants Trust Company, are owned by members. The two largest credit card corporations, Visa and Mastercard, are owned by member banks. (p. 1)

More specifically, they report that the extent of joint ownership among the largest regional ATM networks as of 1993 is as follows:

> Of the largest 10 regional ATM networks, which had an 80 percent share of ATM network transactions, 3 are not-for-profit, essentially cooperatives. Of the remaining 7 for-profit networks, [4 have diffuse ownership shares]. Of the ATM networks ranked from 11 through 20, through which 14 percent of ATM network transactions were conducted, 3 are owned by nonbanks, 3 are owned by single member banks, 1 is owned by a group of only three member banks, and the remaining 3 are owned by a diffuse group of owners. Of the ATM networks ranked from 21 through 50 [through which 6 percent of ATM network transactions were conducted], 5 are owned by nonbanks, 14 by single bank members, 2 by a few banks, and 9 by a large group of banks [in 8 out of those 9 by all members]. (p. 4)

We summarize their observations in Table 2.2 below. As clearly seen in this table, the degree of joint ownership in the US ATM networks is significant, irrespective of the ranking of a network. On average, about 42% of networks ranked 1 through 50 are shown to have diffuse ownership and the figure rises to as much as 90%, when only the networks ranked 1 through 10 are counted.

It had been commonly felt that joint ownership was already an institution that coped with the monopoly pricing problem and that further supervision was unnecessary as Charles Rule (1985), then acting assistant attorney general for the antitrust division of the Department of Justice, put it:

> [T]he likelihood of the direct exercise of market power in interbank switching. . . . is lessened to the extent that ownership and control of the system is more diffuse, and to the extent that the system is operated on a not-for-profit basis. Indeed, the incentive to exercise monopoly power is substantially reduced if the proportions of equity ownership of system participants approximate their respective shares of system usage.

Table 2.2 Ownership of the US regional ATM networks ranked 1 through 50

	Non-bank owner	Single-bank owner	Concentrated bank owners	Diffuse-bank ownership
Ranked 1 Through 10	None	None	MAC (4)	STAR (17)[a], NYCE (7), HONOR (27)[b], MOST (26), PULSE (1489)[a], ACCEL/Exchange (32), YANKEE (9)[a], MAGIC LINE (7), MONEY STATION (7)
Ranked 11 Through 20	MPACT, PRESTO, MONEYMAKER	NETWORK ONE, XPRESS24, JEANIE	BANKMATE (3)	CASH STATION (252), SHAZAM[c], GULFNET (22)
Ranked 21 Through 50	SCS, INSTANT TELLER, FLSERV SHARED, HANDIBANK, CREDIT UNION 24	INSTANT CASH, FASTBANK, EXPRESS, ROCKY MOUNTAIN, EXPRESS TELLER, MONEY BELT, TRANSFUND, BANK OF HAWAII, 7/24 NETWORK, BANKMATE, VIA, MONEY NETWORK, TELLERIFIC, CHECOKARD	QUEST (7), ALERT (9)	TYME (486)[c], KETS (69)[c], NETWORKS (478)[c], THE CO-OP (210)[c], EFT ILLINOIS (247)[c], TX (24) , SC 24 (115)[c], CACTUS NETWORK (48)[c], ALASKA OPTION (8)
Total	8	17	4	21

Source McAndrews and Rob (1985)

Notes * number of owners in parentheses
[a] not-for-profit
[b] ownership capped at 15 percent
[c] all banks participate in the network

This sentiment induced the antitrust authorities to unduly lenient antitrust policy, in their assessment of ATM networks. McAndrews and Rob (1985) calls into question this logic and asserts that joint ownership is associated with high market concentration. That is, they observe that "the frequency of ownership as a not-for-profit or as a diffusely owned joint venture is high and has grown through time, especially among the largest networks." Also, the data suggest that "the markets that are most concentrated (those served by the largest networks) are more likely to be served by shared owner networks" (p. 4). In other words, they show that shared ownership is associated with higher market concentration.

Chapter 3

The Model

Consider a situation where a monopolistic upstream firm provides two downstream firms with a unique and inevitable input at marginal cost $c > 0$.[1] For simplicity, we assume away any other manufacturing or retailing cost downstream.[2] The inverse demand function in the downstream is given by $p = a - b(q_1 + q_2)$ where q_i is the quantity produced by downstream firm i $(i = 1,2)$ and $a > c$, $b > 0$.

We describe the degree of downstream market competition by conjectural variation model, which enables us to examine the effect of downstream competition on the equilibrium outcomes.[3] For simplicity, we assume a symmetric

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[1] The analysis can be easily generalized to the case of n downstream firms. See footnote 12 below.

[2] Later in Section 4.2, we relax this assumption and consider the case when the downstream firms bear asymmetric retailing costs.

[3] The use of conjectural variations approach here is mainly for analytical simplicity to represent the degree of competition. Most results of this thesis does not critically depend on this approach and we can employ other models such as differentiated goods competition model, with much more mathmatical complexity. Many writers in industrial organization and/or international trade theory use this approach when analyzing oligopolistic competition. Also, Dockner (1992) finds "it is possible and justified to interpret a conjectural variations equilibrium as the outcome of dynamic

conjecture of each firm, that is, $\partial q_j / \partial q_i = \beta$ for $i, j = 1,2,\ j \neq i$, where $-1 \leq \beta \leq (q_j / q_i)$ represents the degree of downstream competition: $\beta = -1$ corresponds to Bertrand competition, $\beta = 0$ to Cournot competition and $\beta = q_j / q_i$ (in a symmetric equilibrium $\beta = 1$) to the collusion in the downstream market.

In this setting, we consider two kinds of ownership structures: One is separate ownership where an upstream firm has its own identity as well as the right to determine the interconnection price, and the other is joint ownership.[4] The problem of joint ownership can be thought of as a two-stage game: At the beginning, joint ownership is created and the equity shares of downstream firm i in the upstream entity, $0 \leq s_i \leq 1$ $(i = 1,2)$, are exogenously given, say, by regulatory authorities. We confine our attention to the case of *complete* joint ownership, that is to say, we assume that $s_1 + s_2 = 1$. By this, we need an explicit procedure to determine the interconnection price, since there no longer exists an independent upstream entity who can choose the interconnection price.[5] Also, since the downstream firms with different equity shares may well have different

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strategic interactions." Nevertheless, it should be admitted that conjectural variation model is subject to one serious criticism: It lacks consistency since it relies on the expectation that your opponent would do something different from what they actually do at the equilibrium. This criticism is not unique to conjectural variations approach and Bresnahan (1981) shows that under constant marginal cost assumption, Bertrand equilibrium is “consistent conjectures equilibrium” whereas Cournot equilibrium is not.

[4] Since the focus of analysis will be upon joint ownership, separate ownership alone would be sufficient for reference purposes. The case for vertical integration will be analyzed in Appendix A.

[5] Flath (1989) analyzes the case where downstream firms have only partial equity interests in the upstream firm. In that case, the interconnection price is clearly a decision variable of an upstream firm and the downstream firms only enjoy ‘silent financial interests’.

preferences for the actual interconnection price, it seems plausible to assume that the *realized interconnection price* is the outcome of an associated bargaining procedure between downstream firms.

Therefore, in stage 1, two downstream firms with respective equity shares, s_i, decide their *preferred interconnection price*, w_i $(i = 1,2)$, independently and noncooperatively, and the *realized interconnection price*, w, is the outcome of an associated bargaining process. We suppose several simple bargaining scenarios to represent this stage of the game. Finally, in stage 2 two firms compete in quantities in final good market with a degree of competition β, while taking w as given.

3.1 Separate ownership: Benchmark case

Before deriving the equilibrium outcomes associated with joint ownership, it is useful to consider the case of separate ownership first, for later comparisons.[6] Under separate ownership, there are 3 firms and the profit functions of an upstream firm, π_u, and two downstream firms, π_i $(i = 1,2)$, can be represented as follows:

$$\pi_u(w) = (w - c)(q_1 + q_2), \tag{3.1}$$

$$\pi_i(q_i, q_j) = (p - w)q_i, \text{ for } i, j = 1,2, j \neq i. \tag{3.2}$$

To solve this by backward induction, we first obtain the optimal quantities of

[6] In the terminology of Armstrong and Doyle (1995), this case is equivalent to 'structural separation with liberalization.'

downstream firms as a function of interconnection price, w. Taking the derivative of (3.2) with respect to q_i $(i = 1,2)$ and solving the first-order conditions simultaneously yields

$$q_i(w) = \frac{a - w}{(3+\beta)b}, \text{ for } i = 1,2. \tag{3.3}$$

Equation (3.3) states that optimal quantity of each firm decreases as interconnection price increases, which in turn decreases social welfare. This is essentially an instance of the basic vertical externality of 'double marginalization'. It is well known that this inefficiency can be mitigated (and eventually eliminated) by enhancing downstream competition, which is verified by the inverse relationship between the optimal quantity and the degree of downstream market competition, β (that is, $\partial q_i / \partial\beta < 0$ in equation (3.3)).

Substituting (3.3) into (3.1) and differentiating this with respect to w, equilibrium interconnection price is given by[7]

$$w = \frac{a + c}{2}. \tag{3.4}$$

Note that the upstream monopolist does not care about the downstream competition and always charges the interconnection price of $(a+c)/2$, the reason being that he is a unique supplier of an input and he has no financial interest at all in downstream market. As we shall see below, this is the starting point from which joint ownership can be distinguished from the separate ownership.

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[7] Second-order conditions for both upstream and downstream optimization are also satisfied.

We use an unweighted sum of consumers' surplus and total industry profits as a measure of social welfare. More precisely, since we have assumed linear demand,

$$SW = b(q_1 + q_2)^2 / 2 + \pi_u + \pi_1 + \pi_2 . \tag{3.5}$$

Then, by (3.1), (3.2), (3.3) and (3.4),

$$SW = \frac{(5+2\beta)(a-c)^2}{2b(3+\beta)^2} \tag{3.6}$$

can be obtained. Social welfare increases as downstream market becomes more competitive, which follows from $\partial SW/\partial\beta < 0$ in equation (3.6).

3.2 Joint ownership: Competitive market

Now, let's consider the case where an upstream firm is jointly owned by two downstream firms who in turn Cournot compete in downstream market.[8] At the end of stage 2, downstream firms' profit functions π_i $(i = 1,2)$ can be represented as a sum of their respective upstream and downstream profits. That is,

$$\pi_1(q_1, q_2; w) = s_1(w-c)(q_1 + q_2) + (p-w)q_1 , \tag{3.7}$$

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[8] Referring to the discussion in Chapter 2, this case is more relevant for the US ATM market where member banks compete with one another in downstream market. In the UK electricity market, the salient feature must be the regional monopoly with respective captive markets though adjacent RECs could still find themselves competing to supply large users near their common borders. The case of regional monopoly will be analyzed later in Section 4.1.

$$\pi_2(q_1, q_2; w) = (1-s_1)(w-c)(q_1+q_2)+(p-w)q_2 . \tag{3.8}$$

Differentiating (3.7) and (3.8) with respect to q_1 and q_2 respectively and solving the first-order conditions simultaneously, we can obtain the equilibrium quantities as a function of *realized interconnection price*, w, as follows:[9]

$$q_1(w) = \frac{a-c+[(3+\beta)s_1-2](w-c)}{(3+\beta)b}, \tag{3.9}$$

$$q_2(w) = \frac{a-c+[(1+\beta)-(3+\beta)s_1](w-c)}{(3+\beta)b}. \tag{3.10}$$

Substituting (3.9) and (3.10) into (3.7) and (3.8) respectively, reduced-form profit functions of stage 1 can be expressed as follows:

$$\pi_1(w) = s_1(w-c)Q(w)+(a-bQ(w)-w)q_1(w), \tag{3.11}$$

$$\pi_2(w) = (1-s_1)(w-c)Q(w)+(a-bQ(w)-w)q_2(w), \tag{3.12}$$

where $Q(w) \equiv q_1(w)+q_2(w)$.

To solve for the equilibrium in the first stage (bargaining stage), let's assume, for the moment, that firm 1 is exclusively given the right to determine a common interconnection price.[10] Then, firm 1 will prefer to set the interconnection price at a level to maximize its own profit given by (3.11). We call this level of interconnection price firm 1's *preferred interconnection price* and express this as

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[9] Second-order conditions are also satisfied.

[10] In dealing with control arrangements of production joint ventures between competing firms, Bresnahan and Salop (1986) employs an assumption similar to ours. In theirs, it is called 'control by one parent' arrangement.

w_1. That is,

$$w_1 \in \arg\max_w \pi_1(w). \tag{3.13}$$

Then, the first- and second-order conditions of optimization of (3.11) yield[11]

$$w_1 = \begin{cases} c & ,if\ 0 \le s_1 \le A(\beta), \\ (a+c)/2 & ,if\ A(\beta) < s_1 \le 1, \end{cases} \tag{3.14}$$

where $A(\beta) \equiv 4(1+\beta)/(3+\beta)^2$. Similarly, for firm 2, we can obtain

$$w_2 = \begin{cases} (a+c)/2 & ,if\ 0 \le s_1 < B(\beta), \\ c & ,if\ B(\beta) \le s_1 \le 1, \end{cases} \tag{3.15}$$

where $B(\beta) \equiv (\beta^2 + 2\beta + 5)/(3+\beta)^2$. Note that $0 \le A(\beta) \le 1/2 \le B(\beta) \le 1$, $A(\beta) + B(\beta) = 1$ and $A'(\beta) \ge 0$, $B'(\beta) \le 0$ for $-1 \le \beta \le 1$.[12,13]

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[11] Here, we exclude the possibility of cross-subsidization between upstream and downstream operation, which appears reasonable in view of the regulatory practices in network industries. That is, we confine ourselves to $c \le w_i \le p(w)$ for $i = 1,2$.

[12] In the case of n downstream firms, each firm's *preferred interconnection price* w_i $(i = 1,\cdots,n)$ can be similarly obtained as

$$w_i = \begin{cases} c & ,if\ 0 \le s_i < 4[1+(n-1)\beta]/[n+1+(n-1)\beta]^2, \\ (a+c)/2 & ,if\ 4[1+(n-1)\beta]/[n+1+(n-1)\beta]^2 \le s_i \le 1, \end{cases}$$

where $\sum_{i=1}^{n} s_i = 1$.

[13] At this point, it should be noted that joint-profit maximizing interconnection price is determined to be $(a+c)/2$ by the optimality condition of $\max_w \pi_1(w) + \pi_2(w)$. However, one cannot be

In general, interconnection price implies a source of revenue for upstream operation, whereas it is an input cost for downstream operation. Accordingly, high interconnection price implies a high profit to upstream but a low profit to downstream business, and *vice versa*. Hence, a firm should balance the profitability from both upstream and downstream markets and its preferred target is effectively determined by how much equity shares it owns. There exists a critical level of equity shares which settles this trade-off. That is, in expressions (3.14) and (3.15), it is interesting to observe that an equity share of $A(\beta)$ effectively determines firm 1's preference (similarly $1-B(\beta)$ for firm 2). To illustrate, in the case of Cournot competition ($\beta=0$), it is found to be $A(0)=1-B(0)=4/9\approx 44.4\%$. That is, in case that the firms compete à la Cournot, a firm which owns more than 44.4% of total equity shares would wish to set the interconnection price accordingly highly, and *vice versa*.[14]

Once each firm's *preferred interconnection price* is determined, it seems reasonable to suppose that the *realized interconnection price* is an outcome of an

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quite sure that each firm with different equity shares, and hence different interests, would agree to this level of interconnection price. Instead, it can appear only as a special case of the interplay between w_1 and w_2 given by (3.14) and (3.15), respectively.

[14] The sudden switch in the preferred interconnection prices from low to high price once it attains the threshold upstream share is because the first stage game is a zero-sum game (Note, from equation (3.9) and (3.10), that $Q(w)$ does not depend on s_1). In other words, as s_1 changes within the two regions of upstream shares in (3.13) and (3.14), firms' profit functions move just vertically upward and downward: One firm's increse in profit is just equal to another firm's decrease in profit, hence, the preferred interconnection prices are not related to equity shares. The threshold share of $A(\beta)$ for firm 1 and $1-B(\beta)$ for firm 2 change firms' profit functions from convex to concave and when they are convex, cross-subsidy constraints are binding, making low interconnection price of c as optimal strategies.

appropriate bargaining procedure between (3.14) and (3.15). To keep the analysis as simple as possible, we assume that w is a weighted average of w_i's. That is,

$$w = \alpha w_1 + (1-\alpha) w_2, \tag{3.16}$$

where $0 \le \alpha \le 1$ is bargaining weight imposed on firm 1. In the next Section, we consider several bargaining scenarios which unambiguously fix α in (3.16): Nash bargaining, linear bargaining power and extreme bargaining power scenarios.

3.3 Comparisons of equilibrium outcomes

3.3.1 Nash bargaining

To begin with, let's consider the case where equal weight is given to each firm's *preferred interconnection prices*, regardless of how equity shares are divided between the firms. That is to say, α in (3.16) becomes 1/2 and we call this *Nash bargaining* case. In this case, it is straightforward to obtain the *realized interconnection price* and associated social welfare, which are summarized in the second column of Table 3.1 below.

In Table 3.1, it is interesting to find that the *realized interconnection price* is lower and hence social welfare is greater when there are large asymmetries in the two two firms' equity shares.[15] The intuition behind this result can be explained as

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[15] In the second column of Table 3.1, note that $(a+3c)/4 \le (a+c)/2$ and $(119+66\beta + 7\beta^2)/[12(3+\beta)^2] \ge 1$ for $-1 \le \beta \le 1$. In fact, when cross-subsidies are not permitted, social welfare is a decreasing function of *realized interconnection price* and will be maximized at $w = c$.

follows: When both firms' equity shares are rather great and hence are not different too much from each other ($s_1 \in (A(\beta), B(\beta))$), upstream market becomes more attractive to both of them than downstream market. Hence, they might well prefer *cozy* pie-splitting in upstream to *cumbersome* competition in downstream. Put differently, two firms' interests coincide in such a way as to make them avoid downstream competition and instead enjoy upstream pie-splitting, through the setting of high interconnection price. Hence, they will try to set the interconnection price as high as possible at the expense of consumers ($w_1 = w_2 = w = (a+c)/2$). In this case, the setting of interconnection price can be understood as a sort of device for *tacit collusion.*

On the other hand, if the two firms' equity shares are sufficiently different from each other, there happens a conflict between the firms' interests. In other words, the firm with small share, say firm 1 ($s_1 \in [0, A(\beta)]$), would try to lower the interconnection price as much as possible since there's not so much to be gained for firm 1 in the upstream market ($w_1 = c$ from (3.14)). Whereas, firm 2 with high equity share ($s_2 \in [1 - A(\beta), 1]$) will try exactly the opposite ($w_2 = (a+c)/2$ from (3.15)). As a result, firms' interests are different in such a way as to lower the *realized interconnection price*, which is beneficial to society.

3.3.2 Linear bargaining power

Alternatively, we can imagine a situation where each firm's equity shares correctly reflect its bargaining power. That is to say, a firm with more equity shares might possess higher voice at the bargaining table for the common interconnection price. We call this as *linear bargaining power* scenario, in which α equals s_1. The *realized interconnection price* and associated social welfare can

Table 3.1 Equilibrium outcomes of joint ownership under several bargaining scenarios

Equity share of firm 1 \ Bargaining scenarios		Nash bargaining ($\alpha = 1/2$)	Linear bargaining ($\alpha = s_1$)	Extreme bargaining $\alpha = \begin{cases} 1 & ,if\ s_1 \geq 1/2, \\ 0 & ,if\ s_1 < 1/2 \end{cases}$
Realized inter-connection price	*for* $0 \leq s_1 \leq A(\beta)$	$\frac{a+3c}{4}$	$\frac{(1-s_1)a+(1+s_1)c}{2}$	$\frac{a+c}{2}$
	for $A(\beta) < s_1 < B(\beta)$	$\frac{a+c}{2}$	$\frac{a+c}{2}$	
	for $B(\beta) \leq s_1 \leq 1$	$\frac{a+3c}{4}$	$\frac{s_1 a+(2-s_1)c}{2}$	
Social welfare	*for* $0 \leq s_1 \leq A(\beta)$	$\frac{(119+66\beta+7\beta^2)K}{12(3+\beta)^2}$	$\frac{[27+18\beta+3\beta^2-2s_1(2\beta^2+2\beta-3)-s_1^2(1-\beta)^2]K}{3(3+\beta)^2}$	K
	for $A(\beta) < s_1 < B(\beta)$	K	K	
	for $B(\beta) \leq s_1 \leq 1$	$\frac{(119+66\beta+7\beta^2)K}{12(3+\beta)^2}$	$\frac{[16(2+\beta)-4s_1(1-\beta^2)-s_1^2(1-\beta)^2]K}{3(3+\beta)^2}$	

where $K \equiv 3(a-c)^2/(8b)$.

be similarly calculated as under Nash bargaining case. We present the equilibrium outcomes associated with this case in the third column of Table 3.1, where similar conclusions can be derived as under the Nash bargaining scenario. That is, *realized interconnection price* is lower and associated social welfare is clearly higher when the two firms' equity shares are *appropriately* different from each other.[16]

In this bargaining scenario, a low share firm which prefers low interconnection price, would be always given weaker power in affecting the *realized interconnection price*. Hence, realized interconnection price is decreasing (resp. increasing) and associated social welfare is increasing (resp. decreasing) for $0 \leq s_1 \leq A(\beta)$ (resp. for $B(\beta) \leq s_1 \leq 1$).

3.3.3 Extreme bargaining scenario

Finally, we can imagine an extreme situation in which the bargaining power derived from the status of equity shares is so strong as to provide high share firm with all the decision-making rights, which is exactly the case of majority rule. In this case, it is obvious that the *realized interconnection price* is always determined to be $(a+c)/2$ since the high share firm with exclusive control authority always prefers high interconnection price. The social welfare will always be at its lowest level as seen in the fourth column of Table 3.1. Figure 3.1 below depicts the social welfares under several bargaining scenarios of joint ownership, as well as under separate ownership.

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[16] In the third column of Table 3.1, note that $(1-s_1)a+(1+s_1)c \leq a+c$ and $s_1 a+(2-s_1)c \leq a+c$ and the equalities hold at $s_1 = 0$ and 1 respectively.

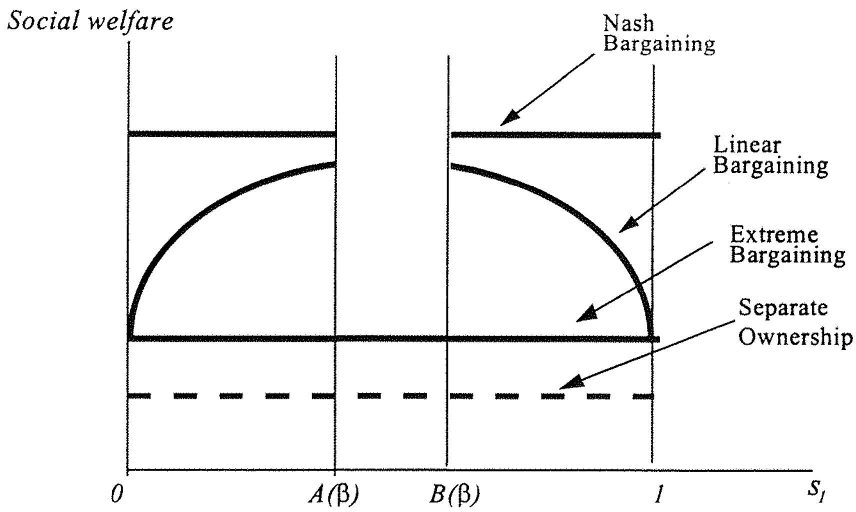

Figure 3.1 Social welfares under separate and joint ownership

3.3.4 Comparisons of social welfares under separate and joint ownership

Now, summarizing the observations obtained thus far, allow us to have:

Proposition 3.1 *The performance of joint ownership is crucially dependent upon how the equity shares are allocated and which bargaining rules are employed. Precisely, interconnection prices and social welfares corresponding to the several bargaining scenarios satisfy the following relationship (Here, 'Sep' stands for 'separate ownership', 'NB', 'Nash bargaining,' 'LB', 'linear bargaining,' and 'EB', 'extreme bargaining scenario.'):*

$$w^{NB} \leq w^{LB} \leq w^{EB} = w^{Sep} \quad and \quad SW^{NB} \geq SW^{LB} \geq SW^{EB} \geq SW^{Sep}.$$

Proposition 1 is the direct result of the following two observations. First, as one moves from Nash bargaining through linear bargaining to extreme bargaining rule, more bargaining power would be given to the high share firm. Second, high share firm will always try to raise the interconnection price, which is detrimental to the society as a whole. As a result, in terms of social welfare it is recommendable to reduce (resp. enhance) high (resp. low) share firm's bargaining power as much as possible, possibly by designing appropriate bargaining schemes. We will explore this in more detail in Section 5.1 below.

Turning to the question of equity share allocation, as already pointed out, when the two firms' equity shares are not very different, there might well emerge an incentive to tacitly collude in setting the common interconnection price. This is, of course, detrimental to society, hence, it is necessary to make asymmetric the initial allocation of equity shares so as to induce the firms' interests diverge.

Proposition 3.2 *From the social welfare point of view, it is necessary to induce downstream firms to have sufficiently (resp. appropriately) heterogeneous equity shares in Nash (resp. linear) bargaining scenarios. In majority rule, respective equity shares are not important at all to social welfare.*

Finally, let's investigate the effect of downstream market competition on the firms' incentives in setting the interconnection price. When the degree of downstream competition increases ($\beta \to -1$), there simultaneously emerge two effects with opposite signs. In the first place, it mitigates the loss from downstream market imperfections, which is certainly beneficial to a society as a whole. Referring to Figure 3.1 above, this welfare increasing effect is represented by an upward shift of all the relevant lines and curves (including the dashed line which represent social welfare under separate ownership), except the horizontal line which represent the social welfare under tacit collusion. This is so because, under tacit collusion, firms would completely give up downstream profits to split upstream pie, hence, the degree of downstream competition does not matter any more.

At the same time, however, increased downstream competition enhances the firms' incentives for tacit collusion in the upstream market. In other words, as downstream market becomes more competitive, the region for tacit collusion, where both firm's interests are coincident, enlarges ($A(\beta)\downarrow, B(\beta)\uparrow$),[17] hence, harms the consumers. The net effect is not clear ex-ante, rather, depend on how the equity shares are initially distributed. After all, we have:

Proposition 3.3 *Under joint ownership, the benefit of encouraging competition in downstream market may be crowded out by correspondingly enhanced incentives for upstream tacit collusion.*

After all, under joint ownership, perfect downstream competition implies perfect tacit collusion in the limit, thus, social welfares associated with all the bargaining scenarios drop abruptly to the point which makes joint ownership indistinguishable to separate ownership.

Finally, with regard to Proposition 3.3, it is noteworthy to mention that if a policy maker who adopts joint ownership as a possible vertical market structure in a certain network industry, could well allocate initial equity shares and, at the same time, appropriately design a bargaining rule, he can attain the social welfare even greater than that under perfect downstream competition in separate

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[17] Recall that $A'(\beta) \geq 0$ and $B'(\beta) \leq 0$ for $-1 \leq \beta \leq 1$.

ownership. If this is the case, the movement of policy focus, from encouraging competition in potentially competitive market, to inducing joint ownership with appropriate consideration on the equity share allocation and bargaining rules, can be justified and recommendable.

Chapter 4

Extensions of the Analysis

In Chapter 3, we have examined the welfare effects of joint ownership structure in terms of a variety of bargaining scenarios. We have found that the performance of joint ownership is crucially dependent upon the initial allocation of equity shares and the bargaining rules employed. In addition, we argue that there may well exist the possibility of tacit collusion among the firms participating in joint ownership, through the setting of common interconnection price. Also, this possibility becomes more likely as the downstream market becomes more competitive. These findings could provide, we believe, useful policy implications in transforming previously integrated or separated markets into joint ownership.

It should, however, be noted that two assumptions have played a crucial role in deriving the equilibrium outcomes of joint ownership. That is, we implicitly assumed that (i) two downstream firms are competitors in the downstream market and (ii) they incur the same marginal downstream cost (with no loss of generality, we further assumed it is zero).

In this Chapter, we relax these assumptions in order to see whether the results previously obtained are valid in more general environments as well, and if so, to obtain more realistic policy implications. First, in Section 4.1, we suppose that the two downstream firms possess their own captive markets, hence behave as regional monopolists rather than mutual competitors. This is exactly the case of the UK electricity distribution market where twelve RECs have their own regional markets so that downstream competition is effectively restricted to the boundaries of the common borders (Department of Energy, 1988). Next, in Section 4.2, we suppose that the downstream firms compete with asymmetric marginal downstream cost, as well as with a common upstream cost.

Together, these two extensions would, we believe, enable us to explore how the conflicts of interests between more and less advantageous firms in downstream market evolve, and what further implications could be obtained. We start by examining the case of regional monopolists first.

4.1 Regional monopolists with respective captive markets

In many instances, downstream firms do not compete head-to-head, rather possess their own (probably geographical) captive markets. As already explained before, in the UK electricity market, adjacent distribution companies act as regional monopolists who have the obligation to supply in their areas, except limitedly competing to supply large users near their common borders.

For this case, we assume that the inverse demand function of each market is given by $p_i = a_i - bq_i$ for $i = 1,2$. The difference between the two markets lies only in the relative size of each market, which can be represented by the difference in the intercept of each inverse demand function.[1] The slopes of each

[1] Department of Energy of the UK (1988) report that "the market for electricity varies from area to area. For instance, 25% of sales by the South Eastern Electricity Board of UK in 1986/1987 were to industrial customers, whereas the figure for industrial sales by the Merseyside and North Wales

market demand function are assumed to be the same, which appears plausible in view of the characteristics of the good in question (say, electricity). Without any loss of generality, we assume that $a_1 \geq a_2$: market 1 is bigger, hence, more profitable than market 2. Also, we assume that $\min\{a_1, a_2\} \geq c$. We first consider the case of separate ownership.

(i) Separate ownership

Under separate ownership, there are three monopolists, one upstream bottleneck monopolist and two downstream regional monopolists. The profit functions of an upstream monopolist, π_u, and two downstream monopolists, $\pi_i\,(i = 1,2)$, can be represented as follows:

$$\pi_u(w) = (w - c)(q_1 + q_2), \tag{4.1}$$

$$\pi_i(q_i) = (p_i - w)q_i, \text{ for } i = 1,2. \tag{4.2}$$

By the same procedure as in Section 3.1, it is straightforward to show that

$$q_i(w) = \frac{a_i - w}{2b}, \text{ for } i = 1,2. \tag{4.3}$$

Expression (4.3) states that monopoly quantities are chosen in each market, which

Electricity Board was 53%." Although precise representation of the distinct characteristics of each captive market, in terms of the factors such as geography and the number and type of customers, is of great interest, it is beyond the scope of this thesis. We here simply ignore these factors other than relative market size, mainly for analytical tractability.

again depend on the absolute market size, a_i. Substituting (4.3) into (4.1) and taking derivative with respect to w, we can find that upstream monopolist determine the interconnection price as[2]

$$w = \frac{a_1 + a_2 + 2c}{4}. \tag{4.4}$$

From (4.1), (4.2), (4.3) and (4.4), together with the fact that demand functions are assumed to be linear, social welfare under separate ownership is easily given by

$$SW = \frac{19(A_1^2 + A_2^2) - 10A_1A_2}{64b}, \tag{4.5}$$

where $A_i \equiv a_i - c \geq 0$ for $i = 1,2$.

(ii) Joint ownership

Under joint ownership, the profit functions of the two downstream monopolists who share the upstream firm, are given by

$$\pi_1(q_1, q_2; w) = s_1(w - c)(q_1 + q_2) + (p_1 - w)q_1, \tag{4.6}$$

$$\pi_2(q_1, q_2; w) = (1 - s_1)(w - c)(q_1 + q_2) + (p_2 - w)q_2, \tag{4.7}$$

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[2] Second-order conditions for both upstream and downstream optimization problems, are also satisfied.

and solving the first-order conditions of optimization simultaneously, yield[3]

$$q_1(w) = \frac{a_1 - w + s_1(w-c)}{2b}, \tag{4.8}$$

$$q_2(w) = \frac{a_2 - w + (1-s_1)(w-c)}{2b}. \tag{4.9}$$

To obtain the equilibrium *preferred interconnection prices*, we follow the same procedure as in Section 3.2. Since cross-subsidization of both directions between upstream and downstream operations is not allowed, from

$$\begin{matrix} w_i \in \arg\max_w \pi_i(w) \\ \textit{subject to } c \le w \le p_i(w) \end{matrix} \quad \text{for } i = 1,2, \tag{4.10}$$

we can obtain

$$w_1 = \begin{cases} c & , if\ 0 \le s_1 < \dfrac{A_1}{A_1 + A_2}, \\ \dfrac{s_1(a_1 + a_2) - a_1 + s_1^2 c}{s_1^2 + 2s_1 - 1} & , if\ \dfrac{A_1}{A_1 + A_2} \le s_1 \le 1. \end{cases} \tag{4.11}$$

The detailed derivations of *preferred interconnection prices* for firm 1 and 2 are relegated to Appendix B1.

The same is true for firm 2 which operates in a smaller captive market, with some qualifications. That is, in order to find firm 2's *preferred interconnection price*, we first need to specify the degree of market size difference. First, when the market sizes are not different too much from each other ($A_2 \le A_1 < \sqrt{2}A_2$), we

[3] Second-order conditions are also satisfied.

have

$$w_2 = \begin{cases} \dfrac{a_2 + (1-s_1)c}{2-s_1} & ,if\ 0 \le s_1 < \dfrac{2\Delta a}{A_1}, \\ \dfrac{a_1 - s_1(a_1 + a_2) + (1-s_1)^2 c}{s_1^2 - 4s_1 + 2} & ,if\ \dfrac{2\Delta a}{A_1} \le s_1 \le \dfrac{A_1}{A_1 + A_2}, \\ c & ,if\ \dfrac{A_1}{A_1 + A_2} < s_1 \le 1, \end{cases} \tag{4.12}$$

where $\Delta a = a_1 - a_2 \ge 0$. On the other hand, when the market size difference is tremendous ($A_1 \ge \sqrt{2}A_2$), we have[4]

$$w_2 = \begin{cases} \dfrac{a_2 + (1-s_1)c}{2-s_1} & ,if\ 0 \le s_1 \le \dfrac{3A_1 - \sqrt{A_1^2 + 2A_2^2}}{2A_1 + A_2}, \\ c & ,if\ \dfrac{3A_1 - \sqrt{A_1^2 + 2A_2^2}}{2A_1 + A_2} < s_1 \le 1. \end{cases} \tag{4.13}$$

In expressions (4.11), (4.12) and (4.13), firms' preferred interconnection prices pass through several (two or three) regimes as equity share changes. This is mainly due to the need to avoid cross-subsidization between upstream and downstream operations. In (4.11), if firm 1's equity share is small, he has every incentive to lower common interconnection price as much as possible, possibly by making a loss in upstream and subsidizing the loss from downstream operation. A restriction on cross subsidization prevents this and the lowest possible price that

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[4] It should be noted that both welfare and joint-profit maximizing interconnection price is $w = c$. As before, there is no reason to believe that the firms with conflicting interests would agree with this price, in the absence of any arrangements for side payments.

firm 1 can achieve is upstream marginal cost of c. On the contrary, if firm 1's equity share is large, he will try to raise the interconnection price, proportionately to his equity share holdings. This will reduce downstream profit, and hence, his preferred interconnection price will rise just moderately since he has no reason to give up his profitable large captive market.

Similar aregument applies to firm 2's incentive, with one noticeable difference. In (4.12) and (4.13), $w_2 = [a_2 + (1-s_1)c]/(2-s_1)$ is a level of interconnection price which is so high to make downstream operation of firm 2 just break even. That is, firm 2 would completely give up its downstream profit if its equity share (and the upstream profit from it) is very great, since he has not so much attractions for downstream captive market as firm 1.

Combining (4.11), (4.12) and (4.13), we have

Proposition 4.1 *Under joint ownership between downstream firms with respective captive markets, one who owns the smaller market resorts to upstream business first, in other words, is more eager to charge high interconnection price than the one who owns the larger market. Moreover, the greater is the market size difference, the clearer become firms' conflicts of interests.*

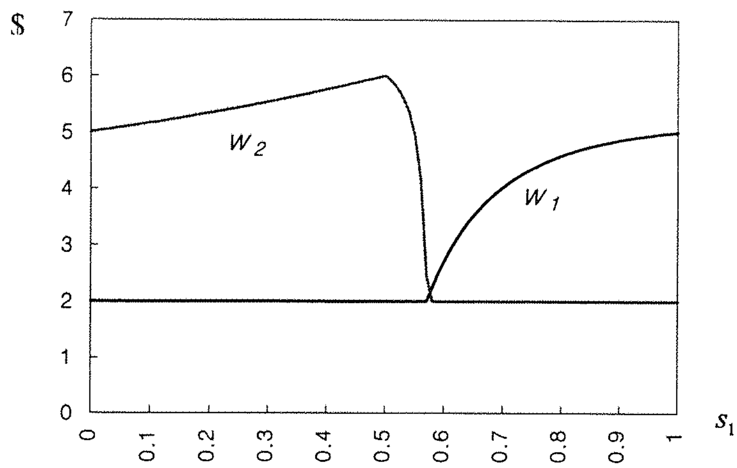
Proof. In expressions (4.11), (4.12) and (4.13), it is obvious that $A_1/(A_1+A_2) \geq 1/2$ by the assumption on relative market sizes. Hence, firm 2 resorts to high interconnection price quicker than firm 1. Also, it can be shown that $(3A_1 - \sqrt{A_1^2+2A_2^2})/(2A_1+A_2) \geq A_1/(A_1+A_2)$ for $A_1 \geq \sqrt{2}A_2$, where the equality holds at $A_1 = \sqrt{2}A_2$. Hence, the bigger is the market size difference, the quicker firm 2 resorts to high interconnection price. Q.E.D.

Behind Proposition 4.1 lies the reason similar to that in the basic model explored in Chapter 3. That is, firms need to balance their profits both in upstream and downstream markets and there exists a critical threshold of equity shares, which determines each firm's interests. If a firm operates in a large, thus, profitable downstream market, it would prefer downstream business to upstream's, unless its equity share is sufficiently great to change its interest. Put it differently, a firm with a large captive market will persist in low levels of interconnection price even for more or less large equity shares, and *vice versa*.

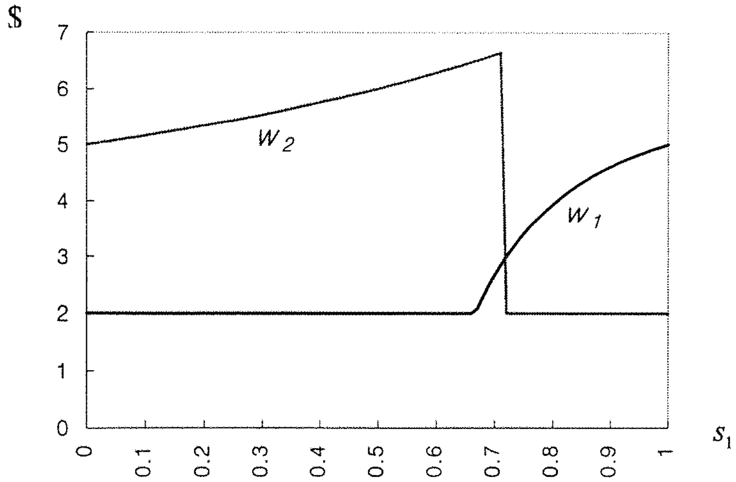
Figure 4.1 below illustrates more clearly the intuitions behind Proposition 4.1. That is, this figure demonstrates how the firms' conflicts of interests surrounding the setting of interconnection price evolve when market sizes are asymmetric and the difference of which increases. In (i) of Figure 4.1, market 1 is only slightly bigger than market 2. But this slight difference is sufficient to diverge the firms' interests. The advantageous firm 1 sticks to the low price until its equity share is so high to make the upstream business promising one, whereas firm 2 moves early to the upstream business since he has little interest in unprofitable downstream market. Also, it is interesting to find that firm 1 moves rather reluctantly to the upstream business, whereas firm 2 moves very quickly giving up the unprofitable downstream business completely. These findings become more salient as the market size difference enlarges, which is shown in (ii) of Figure 4.1.

Turning to the welfare comparisons under separate and joint ownership, it is straightforward and rather tedious to obtain the relevant welfare levels, which we draw in Figure 4.2 below. A quick glance at this figure confirms that joint ownership clearly improves social welfare compared to the separate ownership, in this more general setting as well. Also, it enables us to have the following policy recommendations:

Proposition 4.2 *Under joint ownership between downstream firms with respective captive markets, it is better to allow more equity shares to the one who operates larger captive market. Once equity shares are distributed as such, bargaining rules have little impact on ensuing social welfare.*

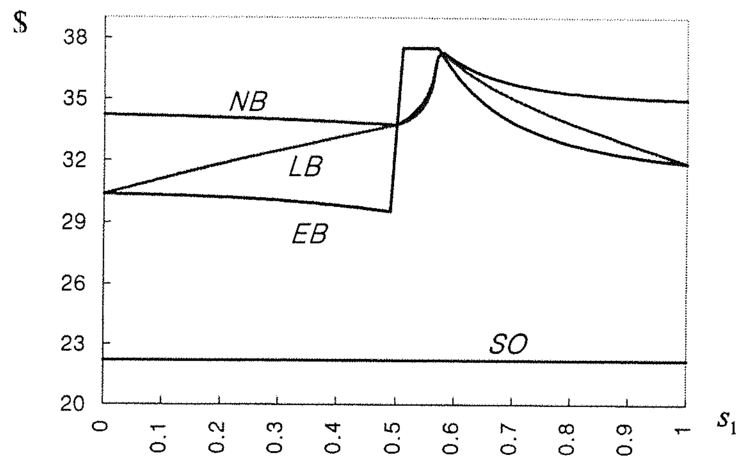


(i) when market size difference is small ($a_1 = 10,\ a_2 = 8,\ c = 2$)

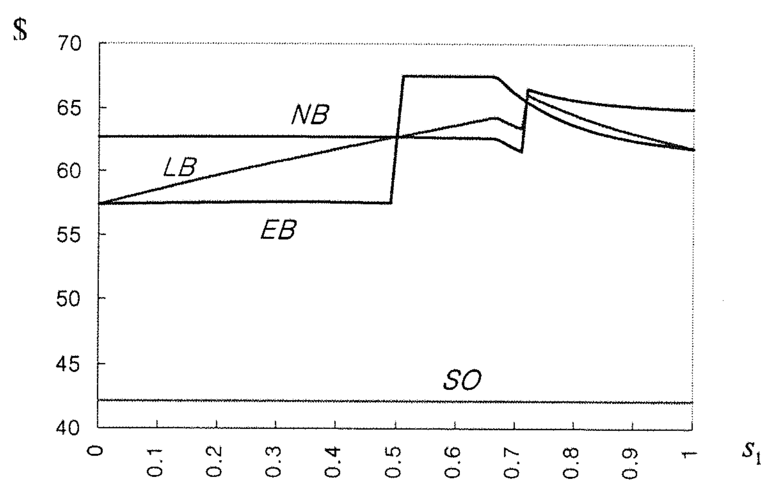


(ii) when market size difference is great ($a_1 = 14,\ a_2 = 8,\ c = 2$)

Figure 4.1 Firms' preferred interconnection prices and resulting conflicts of interests under joint ownership between regional monopolists



(i) when market size difference is small ($a_1 = 10,\ a_2 = 8,\ b = 1,\ c = 2$)



(ii) when market size difference is great ($a_1 = 14,\ a_2 = 8,\ b = 1,\ c = 2$)

Figure 4.2 Social welfares associated with separate and joint ownership
(Regional monopolists with respective captive markets)

4.2 Competing firms with asymmetric downstream costs

Suppose that firm i ($i = 1,2$) faces a marginal downstream cost of c_i as well as an upstream cost of c. Without loss of generality, we assume that firm 1 is more efficient than firm 2 in downstream business, in the sense that $\Delta c \equiv c_2 - c_1 \geq 0$. For expositional simplicity, we here restrict our attention to the case of Cournot competition in conjectural variations approach (that is, $\beta = 0$).[5] We also assume that $a - c - \max\{c_1, c_2\} \geq 0$. We start by considering the separate ownership case first.

(i) Separate ownership

Under separate ownership, one upstream and two downstream firms' profit functions are

$$\pi_u(w) = (w - c)(q_1 + q_2), \tag{4.14}$$

$$\pi_i(q_i, q_j) = (p - w - c_i)q_i, \text{ for } i, j = 1,2,\ j \neq i. \tag{4.15}$$

Applying the same procedure as in the preceding Sections, it is now quite straightforward to derive the equilibrium quantities of the two downstream firms as

[5] This can be justified by the fact that the more similar are marginal downstream costs to each other, the tougher becomes the competition. Hence the similarity in downstream costs can be thought of as a sort of proxy variable for the degree of downstream competition.

$$q_i(w) = \frac{a - w - 2c_i + c_j}{3b}, \text{ for } i, j = 1,2,\ j \neq i, \tag{4.16}$$

and the equilibrium interconnection price of an upstream firm as[6]

$$w = \frac{2a + 2c - c_1 - c_2}{4}. \tag{4.17}$$

The social welfare associated with this interconnection price can also be easily obtained as

$$SW = \frac{20(a-c)(a-c-c_1-c_2) + 41\Delta c^2 + 20c_1c_2}{72b}. \tag{4.18}$$

(ii) Joint ownership

Under joint ownership with asymmetric downstream costs, two downstream firms' profit functions are

$$\pi_1(q_1, q_2; w) = s_1(w-c)(q_1+q_2) + (p - w - c_1)q_1, \tag{4.19}$$

$$\pi_2(q_1, q_2; w) = (1-s_1)(w-c)(q_1+q_2) + (p - w - c_2)q_2. \tag{4.20}$$

From the first-order conditions of optimality, the equilibrium quantities are

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[6] Second-order conditions for both upstream and downstream optimization problems, are also satisfied.

$$q_1(w) = \frac{a - c - 2c_1 + c_2 + (3s_1 - 2)(w - c)}{3b}, \tag{4.21}$$

$$q_2(w) = \frac{a - c + c_1 - 2c_2 + (1 - 3s_1)(w - c)}{3b}. \tag{4.22}$$

Next, we derive the frims' *preferred interconnection prices*.[7] For clarity, we assume that $c_1 = 0$, hence $\Delta c = c_2$, since what matters is a relative, not absolute, size of the downstream costs. Then firm 1's *preferred interconnection price* is

$$w_1 = \begin{cases} c & ,if\ 0 \le s_1 < \frac{4}{9} + \frac{4\Delta c}{9(a-c)}, \\ \frac{a+c}{2} - \frac{2\Delta c}{9s_1 - 4} & ,if\ \frac{4}{9} + \frac{4\Delta c}{9(a-c)} \le s_1 \le 1. \end{cases} \tag{4.23}$$

Also, when the cost difference is not too much ($0 \le \Delta c \le (a-c)/5$), firm 2's *preferred interconnection price* is given by

$$w_2 = \begin{cases} \frac{a+c-c_2}{2} + \frac{2\Delta c}{5 - 9s_1} & ,if\ 0 \le s_1 \le \frac{1}{3}, \\ \frac{a+c+c_2}{2} & ,if\ \frac{1}{3} < s_1 \le \frac{5}{9} + \frac{8\Delta c}{9(a-c-3c_2)}, \\ c & ,if\ \frac{5}{9} + \frac{8\Delta c}{9(a-c-3c_2)} < s_1 \le 1. \end{cases} \tag{4.24}$$

On the contrary, when the cost difference is considerable ($\Delta c > (a-c)/5$), we

---

[7] In this case, joint-profit maximizing interconnection price is given by $w = \min\{(a + c + c_1 + c_2)/2,\ \max[(a + c - c_2 + (9s_1 - 4)\Delta c)/2,\ c]\}$, whereas welfare maximizing interconnection price is $w = \min\{(a + c + c_1 + c_2)/2,\ \max[-a + 2c + c_1 + (9s_1 - 4)\Delta c,\ c]\}$.

have

$$w_2 = \begin{cases} \dfrac{a+c-c_2}{2} + \dfrac{2\Delta c}{5-9s_1} & ,if\ 0 \le s_1 \le \dfrac{1}{3}, \\ \dfrac{a+c+c_2}{2} & ,if\ \dfrac{1}{3} < s_1 \le 1. \end{cases} \tag{4.25}$$

The detailed derivations of these *preferred interconnection prices* for firm 1 and 2 are relegated to Appendix B2, where we solve for the general case of $c_1 \neq 0$.

In expressions (4.23), (4.24) and (4.25), firms' preferred interconnection prices pass through several (two or three) regimes as equity share changes, the reason of which is similar to that offered in Section 4.1. That is, a restriction on cross subsidization prevents firms' incentives to set interconnection price at extremely low or high levels. Note that in (4.24) and (4.25), $w_2 = (a+c+c_2)/2$ is a level of interconnection price which is so high to make downstream operation of firm 2 just break even.

It is interesting to observe that in (4.24) and (4.25), firm 2's preferred interconnection price decreases if its equity share becomes very large (Note that $(a+c-c_2)/2 + 2\Delta c/(5-9s_1) \le (a+c+c_2)/2$ for $0 \le s_1 \le 1/3$). This is because if the actual interconnection price is set high as firm 2 wishes, then the competitive disadvantage of firm 2 in downstream market becomes small, from $(c+c_2)/(c+c_1)$ to $(w_2+c_2)/(w_2+c_1)$. Hence firm 2 needs not completely abandon his downstream business by setting the interconnection price at its highest level.

After all, we have:

Proposition 4.3 *Under joint ownership between the firms with asymmetric* *downstream costs, one who is less efficient downstream resorts to upstream business first, that is, seeks to charge high interconnection price faster than more efficient one. Moreover, when cost difference is quite tremendous, less efficient firm always prefers to charge high interconnection price irrespective of its equity shares.*

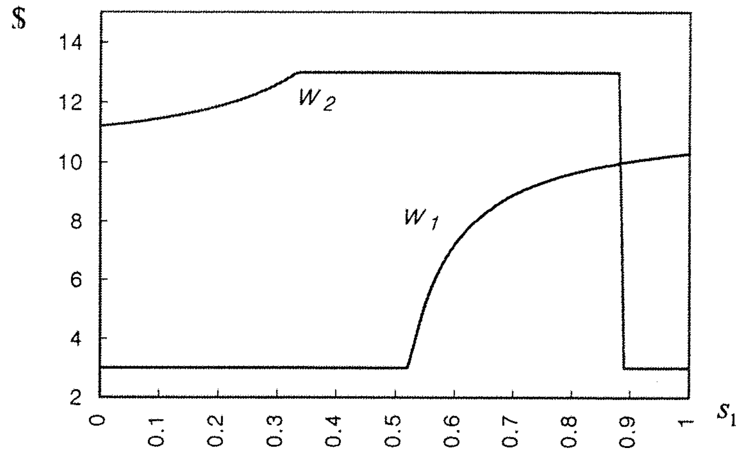
Proof. The first part of the proposition can be proved by examining expressions (4.23) and (4.24), where it can be shown that $[4+4\Delta c/(a-c)]/9 \leq 1-$ $[5+8\Delta c/(a-c-3c_2)]/9$. A brief inspection of expression (4.25) will prove the second part of the proposition. Q.E.D.

The intuition behind Proposition 4.3 is exactly the same as in Proposition 4.1. That is, more efficient firm in downstream market usually prefers downstream competition to upstream pie-splitting, hence, prefers low interconnection price unless its equity share grows too large to change its interest. See Figure 4.3 below. On the contrary, a less efficient firm would be likely to easily change its interest from downstream to upstream business. Even, when the cost disadvantage is tremendous, he tries to keep the interconnection price high however small his equity share is ((ii) of Figure 3).

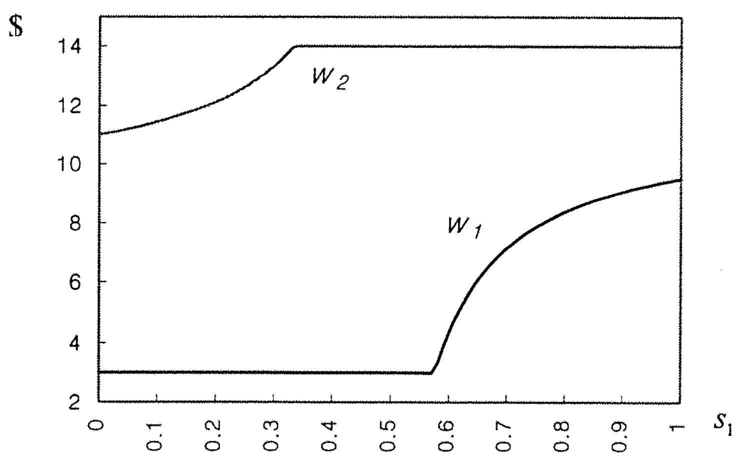
Also, in the same spirit as in Proposition 4.2, we have:

Proposition 4.4 *Under joint ownership between the firms with asymmetric distribution costs, it is recommendable to allow more equity shares to more efficient one. Once equity shares are distributed as such, bargaining rules have little impact on ensuing social welfare.*

Proposition 4.4 above can be verified with the help of Figure 4.4, which compares welfare levels under separate and joint ownership, and in the latter case, under several bargaining rules. In particular, it is interesting to observe that when cost difference is rather great, social welfare may fall short of that under separate ownership (Figure 4.4 (ii)). In this case, policy recommendations of Proposition 4.4 becomes particularly relevant.

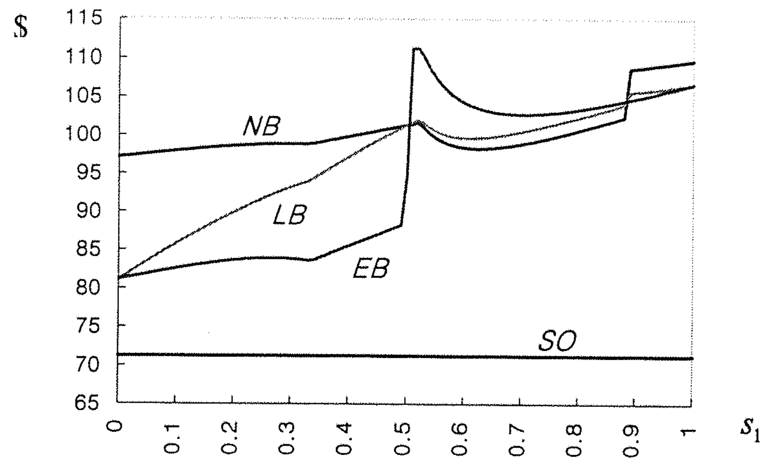


(i) when cost difference is small ($a = 20,\ c_1 = 0,\ c_2 = 3,\ c = 3$)

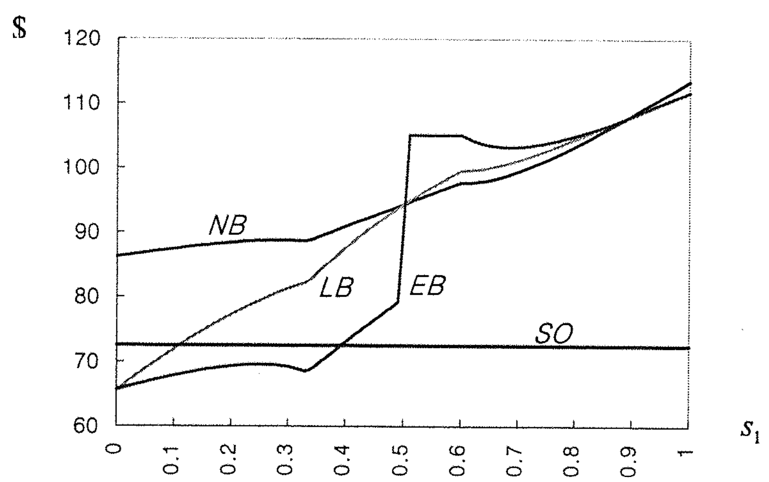


(ii) when cost difference is great ($a = 20,\ c_1 = 0,\ c_2 = 5,\ c = 3$)

Figure 4.3 Firms' preferred interconnection prices and resulting conflicts of interests under joint ownership between asymmetric competing firms



(i) when cost difference is small ($a = 20,\ c_1 = 0,\ c_2 = 3,\ c = 3$)



(ii) when cost difference is great ($a = 20,\ c_1 = 0,\ c_2 = 5,\ c = 3$)

Figure 4.4 Social welfares associated with separate and joint ownership (Competing firms with asymmetric downstream costs)

Chapter 5

Discussion

Having derived major results in the basic and extended models of joint ownership, we now consider various practical and political implications in implementing joint ownership in practice. Since actual adoption of a certain market structure must be much more politically-sensitive and time-consuming than our simple economic analysis suggests, this Chapter would, we believe, provide public policy makers with useful recommendations.

Specifically, this Chapter will include the issue of designing superior bargaining rules, requirement on participation conditions, the effect of vertical market structures on regulatory easiness in a setting where information asymmetry is prevalent, and finally the implication of managerial and institutional conflicts.

5.1 Alternative bargaining rules

In previous Chapter 3 and 4, it has been shown that the performance of joint ownership is crucially dependent upon how initial equity shares are allocated among the participants in joint ownership and which bargaining rules are employed. Accordingly, it may be possible for the policy maker who seeks to maximize social welfare, to design an appropriate rule of game in terms of these two key factors affecting the performance of joint ownership. The former of these two are likely to involve various considerations including political and socio-cultural factors as well as economic ones. Hence, we will discuss only the implication of alternative bargaining rules.

As a simple example, let's consider a situation to which Rubinstein's alternating-move bargaining applies. As already mentioned, *realized interconnection price* can be thought of as a weighted average of *preferred interconnection prices* of each firm. Thus, the bargaining of interconnection prices can be reduced to that of respective bargaining weights, and the well-established solutions of alternating-move bargaining games could be readily applied to this situation as follows:

In the first period, firm 1 proposes its own weight $0 \leq \alpha_1 \leq 1$. After observing this, firm 2 either accepts being satisfied with its own weight $1-\alpha_1$, or rejects and re-offers $0 \leq \alpha_2 \leq 1$ as firm 1's weight, which ends the first period of the game. In the second period, firm 1 either accepts firm 2's re-offer or rejects. There are two versions of this alternating-move bargaining game. In the finite-horizon version, firm 1 will be given an exogenously given weight $0 \leq g \leq 1$ if he rejects firm 2's new offer α_2 and the game ends. On the other hand, in the infinite-horizon version, firm 1 offers a new weight and the same situation continues over and over again until one accepts the other's offer.

It is well known that there exist unique perfect equilibria in both versions of alternating-move bargaining game (Rubinstein, 1982). In the finite-horizon version, the unique equilibrium is firm 1 offers $1-\delta+\delta^2 g$ in the first period and firm 2 accepts this, where $0 \leq \delta \leq 1$ is a discounting rate. In the infinite-horizon version, the unique equilibrium is firm 1 offers $1/(1+\delta)$ in the first period and firm 2 accepts this being satisfied with its weight $\delta / (1+\delta)$.

Turning back to the joint ownership situation, Proposition 3.1 implies that the policy maker's objective is to allow the low share firm as much bargaining power as possible. Hence, it is recommendable to mandate (or encourage at least) the firms to obey the following alternative bargaining rules.

Alternative 1: In finite-horizon bargaining situation, the first offering firm will be unambiguously given a weight of $1-\delta+\delta^2 g$. Hence, if δ is greater than 0.5, let the high share firm to offer first and make g small. Otherwise, let the low share firm to offer first. See Figure 5.1.

Alternative 2: In infinite-horizon bargaining situation, the first offering firm will be always given a higher weight since $1/(1+\delta) \geq 1/2$. So in this case, make the low share firm to offer first.

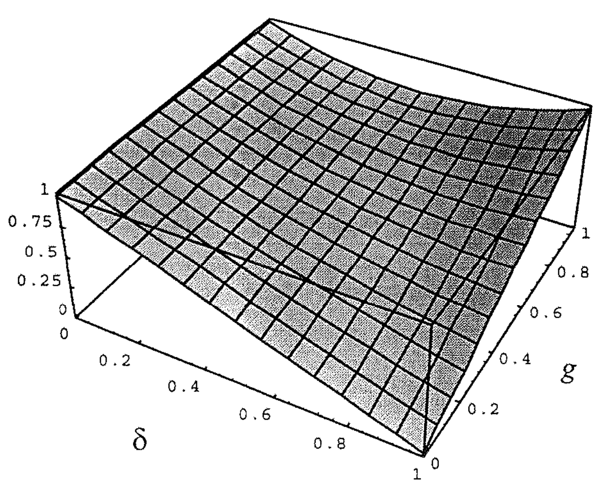


Figure 5.1 The locus of $1-\delta+\delta^2 g$

In real situations, however, it is not likely that this prescription works well since there are various subtle and complicated issues involved in a bargaining process. The worst case arises when the bargaining process is influenced and even entirely dominated by political power (whether it is related to equity share holdings or not) of the high share firm. Hence, keeping the bargaining process itself not to be influenced by the factors other than the economic one should be done before designing a superior bargaining scheme. For this, the government should assume an active role of arbitrator and listen carefully the voice of the weaker. If it were to be found that, for some reason, to make sure the transparency of the bargaining process is very difficult, it must be replaced by the interconnection price regulation which of course is under its own drawbacks. The isssue of regulation will be discussed in Section 5.3 below.

5.2 Participation conditions

In the basic and extended models of joint ownership, we have supposed that the right to choose a certain ownership structure is a policy variable. Even so, however, firms should be ready to involve voluntarily in moving from separate to joint ownership. More precisely, government should guarantee the firms at least the same profit level as that earned under separate ownership. This requires us to consider the participation constraints on the part of the participating firms in joint ownership.

For this, the equity share of a firm and the price of which under joint ownership should be such that the firms can be guaranteed at least the same profit levels as under separate ownership. Therefore, it needs to satisfy

$$\pi_i^{Joint}(s_i) - t \cdot s_i \geq \pi_i^{Separate} \tag{5.1}$$

where $t \cdot s_i$ is the total amount of money which is needed for firm i to buy as much equity share as s_i. It seems possible, albeit rather complicated, to calculate the set $\{t, s_i\}$ which satisfy inequality (5.1) for all the bargaining scenarios considered, which is beyond the scope of this thesis.

5.3 Regulatory implications

In most network industries worldwide, naturally monopolistic markets are usually under tight regulatory oversight, whether it is cost-based (such as rate-of-return regulation) or incentive-based (such as price cap regulation). The potentially competitive market, of course, is not an exception, though the emerging competition in this portion of network industries seems to be gradually replacing regulation. In this Section, we would like to briefly examine how well a regulatory scheme works under joint ownership and whether it can attain the socially optimal level of interconnection prices. For expositional convenience, let's assume that only upstream interconnection price is being regulated, whereas downstream market price is determined by competitive market forces.

When there exists no informational asymmetry with respect to the upstream marginal cost, c, it is obvious that there would be no noticeable differences at all among the ownership structures. In other words, in both separate and joint ownership, regulators could successfully mandate the social welfare maximizing interconnection price with no difficulties (in most cases explored before, it is determined to be $w = c$). However, it is no longer the case when there appears significant informational asymmetries arising from firms' having more accurate cost information than the regulator.

Assume that the firms operating in upstream market have a correct knowledge about its true marginal production cost, whereas the regulator only have a probability distribution about the true status of the cost. Let's further assume that the Baron and Myerson (1982) type regulation applies.

In this situation, we have no mind to explicitly derive the optimal interconnection prices, which would inevitably allow some informational rents to the firms. Rather, we just sketch and compare the plausible outcomes under separate and joint ownership. The point is that in joint ownership, there exist multiple firms upstream who have an access to the true cost information, whereas only a single firm monopolizes the information in separate ownership.

In an appropriate model where information updating process can be explicitly considered, it is highly expected that under joint ownership, there's more likelihood that the cost information can be revealed through time and accordingly updated by the regulator. Also, some kinds of incentive schemes similar to *yardstick competition* could be applied. Therefore, it is highly plausible that the informational rent to the firms will mitigate under joint ownership, which clearly increases social welfare.

5.4 Managerial and institutional conflicts

Finally, it seems noteworthy to briefly consider the managerial and institutional implications of joint ownership, to which we have not paid explicit attention thus far. In particular, we would like to note that, under joint ownership, a number of downstream firms should agree with each other about the operation of naturally monopolistic upstream entity. This might include a number of activities ranging from long-term investment decisions for quality enhancement and capacity expansion, to the various short-term decisions such as the daily operation of the bottleneck facility and the periodic (or minute-by-minute) setting of common interconnection price.

In the model, we have only considered one of the short-term decision problems and depicted the joint decision process by extremely simple bargaining scenarios. It is, of course, too insufficient a proxy to represent a variety of conflicts between the firms participating in the bargaining processes. After all, it is highly conceivable that inefficiencies from managerial and institutional conflicts, such as diseconomies of congestion, may overwhelm the economic benefits from joint ownership. This kind of drawbacks of joint ownership should be remembered and well controlled in implementing joint ownership in practice.[5]

[5] On the contrary, it should also be remembered that joint ownership may accompany other benefits. That is, it might help to alleviate the problem of economic power concentration, which has been one of the serious economic and political problems in most developing countries. In this vein, it is worth recalling that one of the principal aims of privatization in the UK was widening share ownership, and accordingly, gaining political advantage (Vickers and Yarrow, 1988).

Chapter 6

Conclusions

In this thesis, we have examined welfare consequences of joint ownership structure and pointed out that there exist its own merits and drawbacks. In particular, we have found that:

(i) Joint ownership unambiguously increases social welfare compared to the separate ownership by alleviating the problem of 'double marginalization';

(ii) However, due to the danger of tacit collusion in the setting of a common interconnection price, it is recommendable to make asymmetric the allocation of equity shares for downstream firms;

(iii) Also, social welfare can be further increased by an appropriate policy prescription which allows more bargaining power to the low share firm. This is so because high share firm always prefers high interconnection price to the detriment of a society;

(iv) As downstream market becomes more competitive, the region for tacit collusion enlarges. Hence, the virtue of downstream competition could be eroded by the accompanying incentive to collude, unless equity share allocation and bargaining rules are appropriately adjusted; and finally,

(v) When there exist considerable asymmetries among the firms (regional monopolies with asymmetric market sizes and competition with asymmetric downstream costs), firms' conflicts of interests become more evident. That is, one with disadvantageous cost or market conditions will be more eager to charge high interconnection price. This makes it inevitable to allocate more equity shares to an advantageous firm.

We believe that these results would fill the gap in a comprehensive study of vertical market structures. Also, we hope that these results would provide public policy makers who wish to restructure network industries in pursuit of both static and dynamic efficiencies, with useful guidelines and recommendations in selecting appropriate ownership structures. We conclude by mentioning a few limitations of this research and further research directions.

First, the model employed in this thesis flaws from a number of simplifying assumptions including linearity in demand functions, neglect on share-trading stage of a game and very simplified representation of the bargaining processes. To generalize these in a more realistic representation of a real world situation must be a promising future research direction.

Second, as mentioned earlier, the fundamental question of 'What drives different ownership structures?' remains to be solved. To answer this question, however, must require considerable amount of efforts covering both economic and non-economic explanations. The results obtained in this thesis would help to answer this question in a more synthetic and systematic way.

Finally, as Armstrong and Doyle (1995) point out, "it seems plausible that another effect of the joint ownership will be to discourage further entry into the competitive markets." In particular, how to respond to a new entry into downstream market under joint ownership remains to be answered. Possible answers include urging (or inducing) the incumbents to sell a portion of their equity shares to an entrant, allowing the entrant to operate without any equity shares in upstream bottleneck, and so forth.

Appendix A

In this Appendix, we derive the equilibrium outcomes associated with vertical integration, under which there would exist one incumbent who exclusively owns bottleneck facility and an entrant who needs an access to this facility and compete with the incumbent in downstream market. To begin with, profit functions of an incumbent, π_I, and an entrant, π_E, can be represented as follows:

$$\pi_I(q_I; w) = (p-c)q_I + (w-c)q_E, \tag{A.1}$$

$$\pi_E(q_E) = (p-w)q_E. \tag{A.2}$$

In equation (A.1), the first term of the right hand side represents incumbent's downstream profits and the second term, its upstream profits of selling an access to an entrant. To solve this by backward induction, we first obtain the optimal quantities in downstream market as a function of interconnection price, w, which is exclusively determined by the incumbent.

Taking the derivative of (A.1) and (A.2) with respect to q_I and q_E, respectively, and solving the first-order conditions simultaneously yield[1]

$$q_I(w) = \frac{a-(2+\beta)c+(1+\beta)w}{(3+\beta)b}, \tag{A.3}$$

$$q_E(w) = \frac{a+c-2w}{(3+\beta)b}. \tag{A.4}$$

Substituting (A.3) and (A.4) into (A.1) and differentiating this with respect to w,

[1] Second-order conditions for both upstream and downstream optimization are also satisfied.

equilibrium interconnection price of an incumbent is given by

$$w = \frac{a + c}{2}, \tag{A.5}$$

which is the same as under separate ownership given by (3.4), and as under tacit collusion of joint ownership given by Table 3.1. Note that at this level of interconnection price, entrant's quantity q_E given by (A.4) falls to zero. This implies that the incumbent uses his power to control the price of interconnection to bottleneck facility, to foreclose its rival.

Finally, social welfare associated with this vertical market structure is easily given by

$$SW = \frac{3(a - c)^2}{8b}, \tag{A.6}$$

which is the lowest level of social welfare obtained under joint ownership, namely, under tacit collusion (See Table 3.1). Note that the social welfare under vertical integration does not depend on the degree of downstream competition, the reason being that the incumbent always prefers to foreclose the entrant, and thus, to set the interconnection price to squeeze vertically.

Appendix B

In this Appendix, we derive *preferred interconnection prices* of the firms when they are regional monopolists with respective captive markets, and when they compete with asymmetric downstream costs.

B1. Regional monopolists with respective captive markets

To begin with, firm 1's problem can be expressed as follows:

$$Max\ \pi_1(w),$$
$$s.t.\begin{cases} w - c \geq 0, \\ w \leq p_1(w) \Leftrightarrow w - (a_1 + s_1 c)/(1+s_1) \leq 0, \end{cases}$$

Let the solution for this problem be w_1^*. Also, let the solution for unconstrained optimization of $Max\,\pi_1(w)$ be $\hat{w}_1$. Then,

$$\hat{w}_1 = \frac{s_1^2 c - (1-s_1)a_1 + s_1 a_2}{s_1^2 + 2s_1 - 1}.$$

1. When $\pi_1(w)$ is strictly concave. $\Leftrightarrow$ $s_1^2 + 2s_1 - 1 > 0$ $\Leftrightarrow$ $s_1 > \sqrt{2} - 1$,

(i) When $c \leq \hat{w}_1 \leq \dfrac{a_1 + s_1 c}{1 + s_1}$ $\Leftrightarrow$ $\dfrac{A_1}{A_1 + A_2} \leq s_1 \leq 1$, then $w_1^* = \hat{w}_1$,

(ii) When $\hat{w}_1 < c$ $\Leftrightarrow$ $\sqrt{2} - 1 < s_1 < \dfrac{A_1}{A_1 + A_2}$, then $w_1^* = c$,

(iii) When $\hat{w}_1 > \dfrac{a_1 + s_1 c}{1+s_1}$ $\Leftrightarrow$ infeasible.

2. When $\pi_1(w)$ is convex. $\Leftrightarrow$ $s_1^2 + 2s_1 - 1 \le 0$ $\Leftrightarrow$ $s_1 \le \sqrt{2} - 1$,

(i) When $c \le \hat{w}_1 \le \dfrac{a_1 + s_1 c}{1+s_1}$ $\Leftrightarrow$ infeasible,

(ii) When $\hat{w}_1 < c$ $\Leftrightarrow$ infeasible,

(iii) When $\hat{w}_1 > \dfrac{a_1 + s_1 c}{1+s_1}$ $\Leftrightarrow$ $s_1 \le \sqrt{2} - 1$, then $w_1^* = c$.

Hence, we can obtain firm 1's *preferred interconnection price* as in (4.11).

Next, let's consider firm 2's problem, which is given by

$$Max\ \pi_2(w),$$
$$s.t. \begin{cases} w - c \ge 0, \\ w \le p_2(w) \Leftrightarrow w - [a_2 + (1-s_1)c]/(2-s_1) \le 0, \end{cases}$$

and the solution for which is denoted by w_2^*. Similarly for firm 1's case, let the solution for unconstrained optimization be $\hat{w}_2$, which, in turn, is given by

$$\hat{w}_2 = \frac{(1-s_1)^2 c + (1-s_1)a_1 - s_1 a_2}{s_1^2 - 4s_1 + 2}.$$

1. When $\pi_2(w)$ is concave. $\Leftrightarrow$ $s_1^2 - 4s_1 + 2 > 0$ $\Leftrightarrow$ $s_1 < 2 - \sqrt{2}$,

(i) If $A_1 < \sqrt{2} A_2$,

a. When $c \le \hat{w}_2 \le \dfrac{a_2 + (1-s_1)c}{2-s_1}$ $\Leftrightarrow$ $\dfrac{2\Delta a}{A_1} \le s_1 \le \dfrac{A_1}{A_1 + A_2}$, then $w_2^* = \hat{w}_2$,

b. When $\hat{w}_2 < c \Leftrightarrow \dfrac{A_1}{A_1 + A_2} < s_1 < 2-\sqrt{2}$, then $w_2^* = c$,

c. When $\hat{w}_2 > \dfrac{a_2 + (1-s_1)c}{2-s_1} \Leftrightarrow s_1 < \dfrac{2\Delta a}{A_1}$, then $w_2^* = \dfrac{a_2 + (1-s_1)c}{2-s_1}$.

(ii) If $A_1 \geq \sqrt{2} A_2$,

a. When $c \leq \hat{w}_2 \leq \dfrac{a_2 + (1-s_1)c}{2-s_1} \Leftrightarrow$ infeasible,

b. When $\hat{w}_2 < c \Leftrightarrow$ infeasible,

c. When $\hat{w}_2 > \dfrac{a_2 + (1-s_1)c}{2-s_1} \Leftrightarrow s_1 < 2-\sqrt{2}$, then $w_2^* = \dfrac{a_2 + (1-s_1)c}{2-s_1}$.

2. When $\pi_2(w)$ is convex. $\Leftrightarrow s_1^2 - 4s_1 + 2 \leq 0 \Leftrightarrow s_1 \geq 2-\sqrt{2}$,

(i) If $A_1 < \sqrt{2} A_2$,

a. When $c \leq \hat{w}_2 \leq \dfrac{a_2 + (1-s_1)c}{2-s_1} \Leftrightarrow$ infeasible,

b. When $\hat{w}_2 < c \Leftrightarrow$ infeasible,

c. When $\hat{w}_2 > \dfrac{a_2 + (1-s_1)c}{2-s_1} \Leftrightarrow s_1 \geq 2-\sqrt{2}$, then $w_2^* = c$.

(ii) If $\sqrt{2} A_2 \leq A_1 < 2A_2$,

a. When $c \leq \hat{w}_2 \leq \dfrac{a_2 + (1-s_1)c}{2-s_1} \Leftrightarrow \dfrac{A_1}{A_1 + A_2} \leq s_1 \leq \dfrac{2\Delta a}{A_1}$,

a-1. When $\dfrac{A_1}{A_1 + A_2} \leq s_1 \leq \dfrac{3A_1 - \sqrt{A_1^2 + 2A_2^2}}{2A_1 + A_2}$, then $w_2^* = \dfrac{a_2 + (1-s_1)c}{2-s_1}$, a-2. When $\frac{3A_1 - \sqrt{A_1^2 + 2A_2^2}}{2A_1 + A_2} < s_1 \leq \frac{2\Delta a}{A_1}$, then $w_2^* = c$,

b. When $\hat{w}_2 < c \Leftrightarrow 2 - \sqrt{2} \leq s_1 < \frac{A_1}{A_1 + A_2}$, then $w_2^* = \frac{a_2 + (1 - s_1)c}{2 - s_1}$,

c. When $\hat{w}_2 > \frac{a_2 + (1 - s_1)c}{2 - s_1} \Leftrightarrow s_1 > \frac{2\Delta a}{A_1}$, then $w_2^* = c$.

(iii) If $A_1 \geq 2A_2$,

a. When $c \leq \hat{w}_2 \leq \frac{a_2 + (1 - s_1)c}{2 - s_1} \Leftrightarrow \frac{A_1}{A_1 + A_2} \leq s_1 \leq 1$,

a-1. When $\frac{A_1}{A_1 + A_2} \leq s_1 \leq \frac{3A_1 - \sqrt{A_1^2 + 2A_2^2}}{2A_1 + A_2}$, then $w_2^* = \frac{a_2 + (1 - s_1)c}{2 - s_1}$,

a-2. When $\frac{3A_1 - \sqrt{A_1^2 + 2A_2^2}}{2A_1 + A_2} < s_1 \leq 1$, then $w_2^* = c$,

b. When $\hat{w}_2 < c \Leftrightarrow 2 - \sqrt{2} \leq s_1 < \frac{A_1}{A_1 + A_2}$, then $w_2^* = \frac{a_2 + (1 - s_1)c}{2 - s_1}$,

c. When $\hat{w}_2 > \frac{a_2 + (1 - s_1)c}{2 - s_1} \Leftrightarrow$ infeasible.

Hence, we can obtain firm 2's *preferred interconnection price* as given by (4.12) if $A_1 < \sqrt{2}A_2$, and by (4.13) if $A_1 \geq \sqrt{2}A_2$.

B2. Competing firms with asymmetric downstream costs

Firm 1's problem can be represented as follows:

$$Max\ \pi_1(w),$$
$$s.t.\begin{cases} w-c \geq 0, \\ w \leq p(w) \Leftrightarrow w-(a+c+c_1+c_2)/2 \leq 0. \end{cases}$$

Let the solution for this problem and for unconstrained optimization be w_1^* and $\widetilde{w}_1$, respectively. Then,

$$\widetilde{w}_1 = \frac{a+c-c_1}{2} - \frac{2\Delta c}{9s_1 - 4}.$$

1. When $\pi_1(w)$ is concave. $\Leftrightarrow$ $s_1 > 4/9$,

(i) When $c \leq \widetilde{w}_1 \leq \frac{a+c+c_1+c_2}{2}$ $\Leftrightarrow$ $s_1 \geq \frac{4}{9} + \frac{4\Delta c}{9(a-c-c_1)}$, then $w_1^* = \widetilde{w}_1$,

(ii) When $\widetilde{w}_1 < c$ $\Leftrightarrow$ $\frac{4}{9} < s_1 < \frac{4}{9} + \frac{4\Delta c}{9(a-c-c_1)}$, then $w_1^* = c$,

(iii) When $\widetilde{w}_1 > \frac{a+c+c_1+c_2}{2}$ $\Leftrightarrow$ infeasible.

2. When $\pi_1(w)$ is convex. $\Leftrightarrow$ $s_1 \leq 4/9$,

(i) When $c \leq \widetilde{w}_1 \leq \frac{a+c+c_1+c_2}{2}$ $\Leftrightarrow$ $s_1 \leq \frac{4}{9} - \frac{4\Delta c}{9(2c_1+c_2)}$,

a. if $a-c-3c_1-c_2 > 0$ or $a-c-3c_1-c_2 \leq 0$ and $a-c \geq 5c_1 - c_2$, then $w_1^* = c$,

b. if $a-c-3c_1-c_2 \leq 0$ and $a-c < 5c_1 - c_2$, b-1. When $\frac{4}{9}+\frac{8\Delta c}{9(a-c-3c_1-c_2)} \le s_1 \le \frac{4}{9}-\frac{4\Delta c}{9(2c_1+c_2)}$, $w_1^* = c$,

b-2. When, $s_1 < \frac{4}{9}+\frac{8\Delta c}{9(a-c-3c_1-c_2)}$, then $w_1^* = \frac{a+c+c_1+c_2}{2}$,

(ii) When $\tilde{w}_1 < c \Leftrightarrow$ infeasible,

(iii) When $\tilde{w}_1 > \frac{a+c+c_1+c_2}{2} \Leftrightarrow \frac{4}{9}-\frac{4\Delta c}{9(2c_1+c_2)} < s_1 \le \frac{4}{9}$, then $w_1^* = c$.

Hence, firm 1's *preferred interconnection price* is obtained as in (4.23).

Next, firm 2's problem is as follows:

$$
\begin{aligned}
&Max\ \pi_2(w),\\
&s.t. \begin{cases} w-c \ge 0, \\ w \le p(w) \Leftrightarrow w-(a+c+c_1+c_2)/2 \le 0. \end{cases}
\end{aligned}
$$

Let the solution for this and for unconstrained optimization be w_2^* and $\tilde{w}_2$, respectively. Then,

$$
\tilde{w}_2 = \frac{a+c-c_2}{2} - \frac{2\Delta c}{9s_1-5}.
$$

1. When $\pi_2(w)$ is concave. $\Leftrightarrow s_1 < 5/9$,

(i) When $c \le \tilde{w}_2 \le \frac{a+c+c_1+c_2}{2} \Leftrightarrow s_1 \le \frac{5}{9}-\frac{4\Delta c}{9(c_1+2c_2)}$, then $w_2^* = \tilde{w}_2$,

(ii) When $\tilde{w}_2 < c \Leftrightarrow$ infeasible,

(iii) When $\tilde{w}_2 > \frac{a+c+c_1+c_2}{2} \Leftrightarrow \frac{5}{9}-\frac{4\Delta c}{9(c_1+2c_2)} < s_1 < \frac{5}{9}$, then

$$w_2^* = \frac{a + c + c_1 + c_2}{2}.$$

2. When $\pi_2(w)$ is convex. $\Leftrightarrow$ $s_1 \geq 5/9$,

(i) When $c \leq \widetilde{w}_2 \leq \frac{a + c + c_1 + c_2}{2}$ $\Leftrightarrow$ $s_1 \geq \frac{5}{9} + \frac{4\Delta c}{9(a - c - c_2)}$,

a. if $a - c - c_1 - 3c_2 < 0$ or $a - c - c_1 - 3c_2 \geq 0$ and $a - c < 5c_2 - c_1$, then

$$w_2^* = \frac{a + c + c_1 + c_2}{2},$$

b. if $a - c - c_1 - 3c_2 \geq 0$ and $a - c \geq 5c_2 - c_1$,

b-1. When $\frac{5}{9} + \frac{4\Delta c}{9(a - c - c_2)} \leq s_1 \leq \frac{5}{9} + \frac{8\Delta c}{9(a - c - c_1 - 3c_2)}$, then

$$w_2^* = \frac{a + c + c_1 + c_2}{2},$$

b-2. When $s_1 > \frac{5}{9} + \frac{8\Delta c}{9(a - c - c_1 - 3c_2)}$, then $w_2^* = c$,

(ii) When $\widetilde{w}_2 < c$ $\Leftrightarrow$ $\frac{5}{9} \leq s_1 < \frac{5}{9} + \frac{4\Delta c}{9(a - c - c_2)}$, then $w_2^* = \frac{a + c + c_1 + c_2}{2}$,

(iii) When $\widetilde{w}_2 > \frac{a + c + c_1 + c_2}{2}$ $\Leftrightarrow$ infeasible.

Hence, firm 2's *preferred interconnection price* is obtain as in (4.24) and (4.25), since we assumed $c_1 = 0$.

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