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Negotiations Over Intellectual Property Protection: A Strategic Bargaining Aspect

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Abstract: This paper provides a bargaining aspect into the analysis of intellectual property protection across borders. We investigate the conditions under which a mutually accepted level of intellectual property enforcement can be agreed upon between two negotiating governments. We also explore the implications for optimal R&D of the varying degree of intellectual property protection. We find that intellectual property infringement need not always hamper an innovator's investment choices; zero patenting across borders can be a mutually agreed level of protection in equilibrium; and the degree of 'trust' can have a significant impact on the negotiation outcome.

Key words: intellectual property rights; strategic bargaining; innovation; imitation

JEL Classification: C78, F13

Introduction

This paper provides a bargaining analysis into the direct negotiations over a mutually accepted level of intellectual property enforcement across borders. In contrast to the previous trade-related intellectual property rights (TRIPs) literature emphasising the welfare implications of patent protection (see, for instance, Aoki and Prusa, 1993; Chin and Grossman, 1990; Diwan and Rodrik, 1991; Žigić, 1998, 2000), we study the attempt to strike a deal consisting of a mutually accepted level of IP protection and a lump sum transfer payment between two governments in the context of trade negotiation. We employ the Nash bargaining framework to study the negotiations

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between a Northern government and a Southern government representing the innovating firm and the imitating firm, respectively. A central assumption is that the governments can negotiate on behalf of their domestic firms. The government is considered as an agent that can commit to standards of intellectual property enforcement before the firms spend on R&D or choose for IP volation. And the role of government can be better understood with reference to the growing importance of multilateral negotiation forum in a broader context of gobal economic system.

Two main reasons justify the motivation for current research. One is the use of domestic policy instruments to achieve objectives at the international level. Indeed, in response to the pleas for assistance from their innovating corporate sectors in the light of lost revenue and profits from piracy, the Northern governments have put pressure on the South to provide stronger enforcement of property rights and by pushing for new codes of international conduct. Subsequently, threat for retaliation arising from unilaterally-defined unfair trade practices (cf. Bhagwati and Patrick, 1990; Benko, 1987; Markus, 1990) suggests that direct negotiation seem to have become an effective form of policy device, in contrast to tariffs and others. The other is that lawsuits or appeals against foreign infringement appear implausible in the absence of a transnational agreement on protection when an imitator can easily replicate intellectual property products at very low cost.

This paper also investigates the following issues: is it true that his ex-ante research incentives be hampered once an innovator, recognising his own R&D efforts, strengthens his competitors without receiving adequate compensation? How do the innovator and the imitator agree to a mutually accepted level of protection in light of the different nature of production of the intellectual property products? Is it true that an agreed level of patent protection will always be honestly implemented? If not, how is it affected by the degree of trust the nature of intellectual property agreement?

We build in the 'R&D with spillovers' type of model[1] the negotiations between two governments over an agreed level of intellectual property enforcement and the amount of compensation. We demonstrate that intellectual property infringement has a negative impact on R&D investment only when both the initial marginal cost and the degree of technology copying are high. Hence, a zero patening agreement and, thus, zero transfer payment, can be an efficient bargaining outcome. In light of the repetitive enlisiting of some of her trading partners in the priority watch list as announced by the United States Trade Represenative, we further explore the issue of trust. We show that, if the degree of trust is very low, then zero protection emerges as an efficient bargaining outcome. This result suggests that the element of distrust in negotiations may lead to bargaining impasse.

The remainder of the paper is organised as follows. Section 2 describes the assumptions of the analyzed two-stage game between the Northern innovator and the Southern imitator, where the innovator spends on R&D and the imitator conducts no

R&D but copies, examines the conditions under which specific market forms emerge in equilibrium, and explains the implications for optimal Northern R&D expenditure of the level of intellectual property infringement. In Section 3, government is introduced and we explore the conditions upon which efficient intellectual property enforcement can be agreed. Section 4 investigates the issues of trust involved in negotiations. Section 5 concludes.

The Basic Model

We consider, in this model, a situation in which two firms produce homogeneous products, choose simultaneously their quantities, and compete in a common market (which does not fall within the borders of either firm[2]). In this game, the innovating firm (denoted by firm R) and the imitating firm (denoated by firm I) are the two players. At the first stage, firm R decides on the amount of research expenditure; firm I conducts no research, but can copy some of firm R's research outcome[3]. After firm I having copied firm R's research outcome to any extent possible, in the second stage, the two firms engage in a Cournot competition. The payoff to each firm is its profit.

Before setting the quantities to be produced, firm R invests in a deterministic process innovation allowing the innovator to reduce its marginal cost of production. We characterise the research technology with regular properties of concave function in a specific manner, i.e. after spending an amount of research expenditure $h \geq 0$ on R&D, the marginal cost of production is reduced by $2\sqrt{h}$, to capture the existance of dimishing returns to research expenditure (cf. D'Aspremont and Jacquemin, 1988; Chin and Grossman, 1990; Žigić, 1998, 2000).

The other firm (firm I) does no research. However, exogenously and before quantities are chosen, it is able to copy some of firm R's research outcome (as captured by α) in the manner specified below.

Let $\bar{c}$ (where $0 < \bar{c} < 1$) denote the (common) initial marginal cost to firms R and I, the 'post-innovation' marginal cost of production of each firm is given by:

$$c_R = \max\left\{0, \bar{c} - 2\sqrt{h}\right\}, \tag{1}$$

$$c_I = \max\left\{0, \bar{c} - 2\alpha\sqrt{h}\right\} \tag{2}$$

where $0 \leq \alpha \leq 1$ represents the extent (or degree) to which firm I can copy from firm R[4]. The parameter α, which is exogenously specified here, may be interpreted as a parameter capturing the cost of copying (imitation) and/or the degree of patent protection. The higher the value of α, the lower is the cost of imitation and/or the lower is the extent of patent protection. If $\alpha = 0$, then firm I is not able to copy any of firm R's research outcome; at the other extreme, if $\alpha = 1$, then firm I copies the full research outcome of firm R; and intermediate values of α ($0 < \alpha < 1$) mean that only some of firm R's research outcome is copied.

Although the characterisation of 'R&D production function' in the current model may implicitly assume 'that the R&D process is overly efficient' and, thus, limit 'the scope of the analysis to the very special case'[5], the object here is to demonstrate that the policy implications for optimal research investment need not be all satisfactory even with general specification of a concave R&D function exhibiting $f(0)=0$, $f'(h)>0$ and $f''(h)<0$ and that the effectiveness of an innovator's R&D process should be taken into account while investigating the issues related to 'R&D with spillovers'.

To bring out the main insights in a simple manner, we adopt a linear inverse demand function:

$$P(Y) = \begin{cases} 1 - Y, 0 \leq Y < 1 \\ 0, otherwise \end{cases} \tag{3}$$

where $Y = y_R + y_I$, with y_R and y_I denoting the quantities produced by firm R and firm I, respectively. Notice the unitary normalization of demand intercept implies a 'standardised' market size, resulting in the unit costs to be less than one. Although a general specification of the market size parameter, e.g., A, can provide interesting outcomes, in particular, when optimal research is large, the qualitative results of the present model and the implications for optimal research investment remains unimpaired[6].

Profits to the firms are given by:

$$\pi_R = [P(Y) - c_R] y_R - h, \tag{4}$$

$$\pi_I = [P(Y) - c_I] y_I . \tag{5}$$

We assume that the game form is common knowledge between the players. The solution concept of subgame perfect equilibrium (SPE henceforth) is employed to analyse this market game. We begin our analysis by first deriving the equilibrium output levels at the second stage. Then, using this, we derive the equilibrium research expenditure of firm R at the first stage. The objective is to explore the equilibrium amount of R&D investment in the presence of intellectual property infringement.

Equilibrium R&D with Intellectual Property Infringement

Proposition 2. 1: In the presence of intellectual property infringement,

(1) if, in equilibrium, monopoly market structure emerges, then the innovating firm's R&D decision is not affected by infriengment. Specifically, $h^* = \bar{h} = \bar{c}^2 / 4$ for any $0 \le \bar{c} \le 4/9$ and $0 \le \alpha \le 1$;

(2) if, in equilibrium, duopoly market structure emerges, then, for any high cost $4/0 < \bar{c} < 1$,

(a) the innovator's research expenditure remains unaffected provided the degree of copying is not too high, i.e., $h^* = \bar{h} = \bar{c}^2 / 4$ for any $0 \le \alpha \le \alpha^*$; and

(b) the innovator reduces its research expenditure if the degree of copying is very high, i.e.,

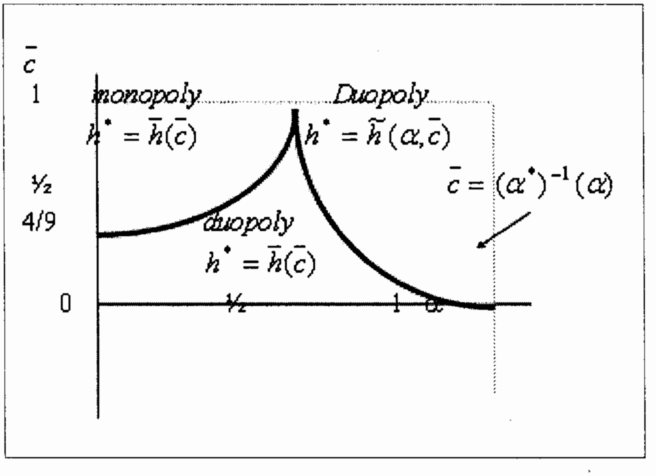
$$h^* = \tilde{h} = \left(\frac{(4 - 2\alpha(1 - \bar{c})}{(2\alpha - 1)(7 - 2\alpha)} \right)^2 \text{ for any } \alpha^* < \alpha \le 1,$$

$$\text{where } \alpha^* = \left[(1 + 3\bar{c}) - \sqrt{1 - 2\bar{c} + 10\bar{c}^2} \right] / 2\bar{c}.$$

Proof: See Appendix A.

Figure 2.1 characterises, in equilibrium, the product market structure and the amount of R&D investment in the space.

Figure 2.1



An important message emerges from Proposition 2.1: the policy calling for the complete elimination of intellecual property infringement (to enhance the innovator's incentive to conduct R&D) may be unnecessary. We have deomonstrated that, the price of R&D can be as important an element in influencing an innovator's investment decision as intellectual property infringement, and that the market structure in equilibrium, resulting from the interplay between the cost of R&D and the degree of copying, plays a significant role in affecting the research expenditure. Thus, contrary to the general belief that lax patent protection is detrimental to the innovating firm's intention for innovation (e.g. USITC, 1988), intellectual property infringement need not definitely affect an innovator's decision towards R&D.

Intuitively, a low initial marginal cost suggests it is relatively cheap to engage in research innovation. And a small degree of infringement allows for a great cost differential between the innovator and the imitator. In the limit, as the degree of copying shrinks to zero, the innovator has an absolute advantage in production cost, and, thus, the output produced by the imitator is negligible. Starting from these conditions, an increase in the degree of infringement reduces the cost differential and brings about stronger competition in the product market. Hence, even though with diminishing returns to investment, the latter becomes less profitable for high initial costs on one hand; and high cost makes cost cutting more important especially if it results in a cost advantage to rivals, on the other. This explains why research investment can be hampered with easy infringement. Nevertheless, an innovator can enjoy the gains from conducting R&D provided the initial marginal cost is low.

The Bargaining Model

We now study a situation in which the value of is endogenously determined through negotiations. More precisely, before the two firms play a two-stage game of R&D and output, two governments, G_R and G_I, representing the innovating firm R and the imitating firm I, respectively, negotiate over a set of agreement (α, T)[7]. Suppose that agreement is reached on a pair (α, T) - where $\alpha \in [0,1]$ and $T \in \Re$ - then the payoffs to the governments are given by:

$$U_R(\alpha,T)=\pi_R^*(\alpha)-T \tag{6}$$

$$U_I(\alpha,T)=\pi_I^*(\alpha)+T \tag{7}$$

where $\pi_R^*(\alpha)$ and $\pi_I^*(\alpha)$ are the unique SPE payoffs to firms R and I - as suggested by Proposition 2.1.

Note, if we interpret the value of as a *patenting* parameter, that this setting characterises a situation where G_R, in view of technology copying taking place abroad, makes a monetary compensation T to G_I to induce a better protection on firm

R's research output. Hence, the value of α now represents a mutually accepted level of patent enforcement to be implemented in country I. And if $\alpha = 0$, then government I agrees to provide the most stringent patenting system for foreign intellectual property (IP) products and, consequently, none of firm R's research output is copied; if $\alpha = 1$, government I provides foreign IP products no protection at all and, thus, firm R's research output can be completely copied; intermediate values of α imply *incomplete* patent protection and the lower the value of α, the more stringent is the patenting system provided by government I. The parameter T represents a lump-sum monetary transfer given from G_R to G_I. Alternatively, it is possible to interpret T as a bribe or simply an incentive scheme aiming at inducing a stronger foreign patenting for the exports of domestic IP products[8].

Notice that the *patenting* interpretation for the value of α[9] is meant to reflect the imitating government's effort in policing its domestic infringement on foreign firm R's research outcome. A low value of could imply G_I either increases the number of inspectors recruited to investigate the unauthorised use of intellectual property products, or G_I imposes a significant penalty (a fine or the cost of imprisonment) to an imitator should he be brought to court and be successfully prosecuted for patent infringement.

We employ the framework established by Nash (1950) to study this bargaining situation in which two governments negotiate over a set of agreement - the degree of patent protection (α) and the amount of transfer payment (T). The set of feasible utility pairs that can result from any agreement, denoted as Ω, is

$$\Omega = \{(u_R, u_I): \exists\alpha \in [0,1] \text{ and } T \in \Re \text{ such that}$$

$$U_R(\alpha, T) = u_R \text{ and } U_I(\alpha, T) = u_I\} \tag{8}$$

If the two governments disagree, then there is no patent protection ($\alpha = 1$) and thus zero transfer payment ($T = 0$). This implies that, in disagreement, the reservation utility pair $d = (d_R, d_I)$ is $d_R = U_R(1,0)$, and $d_I(1,0)$.

The Nash bargaining solution (NBS) is used to characterise the bargaining outcome[10]. In the NBS, the negotiated outcome, (u_R^N, u_I^N), is the solution to:

$$\begin{aligned} &\underset{(u_R, u_I)}{Max}(u_R - d_R)(u_I - d_I) \\ &s.t.(u_R, u_I) \in \Omega, u_R \geq d_R \text{ and } u_I \geq d_I \end{aligned} \tag{9}$$

where $(u_R - d_R)(u_I - d_I)$ is the Nash product.

The Bargaining Equilibrium

Proposition 3.1 characterises the efficient level of intellectual property protection in the NBS. And Figure 3.2 characterises the degree of patent protection, α^N, in the NBS as a function of $\bar{c}$.

Proposition 3. 1: [Efficient Intellectual Property Protection in the NBS]

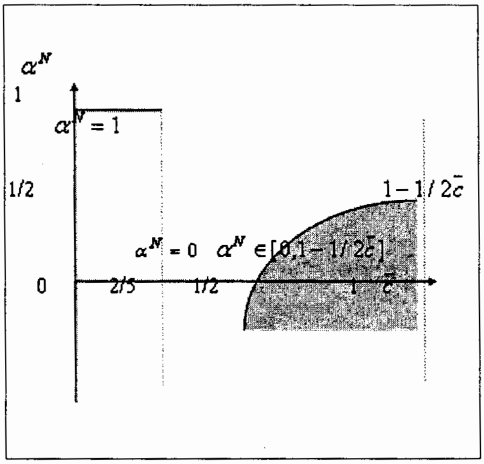
(a) *If* $\bar{c} \in (0,2/5]$, *then* $\alpha^N = 1$;

(b) *If* $\bar{c} \in [2/5,1/2)$, *then* $\alpha^N = 0$; *and*

(c) *If* $\bar{c} \in [1/2,1)$, *then* $\alpha^N \in [0,1-1/2\bar{c}]$.

Proof: See Appendix B.

Figure 3.1



The intuition behind this result is straightforward: G_R and G_I set the degree of intellectual property protection to the level which maximises the gains from agreement (as represented by the joint utility $U_R + U_I \equiv \pi^*_R(\alpha) + \pi^*_I(\alpha^*)$), and use the transfer payment as an instrument to divide the generated surplus $\pi^*_R(\alpha^*) + \pi^*_I(\alpha^*)$.

Proposition 3.1 suggests, depending on the value of the initial marginal cost, that a patenting system characterised by zero or some protection can be efficient, and thus, be part of the NBS (and, in fact, any efficient bargaining solution). Thus, if the initial marginal cost is sufficiently low, then the two governments may agree to no patent protection. As the initial marginal cost increases, the joint utility rises with a stronger patenting system (i.e., a lower). This implies that there exist potential gains from agreement, and that two governments may sign up a patenting treaty, with government I providing a more stringent intellectual property protection.

Notice that the degree of efficient patent is *discontinuous* at $\bar{c}=2/5$. This occurs because the utility pair to the two governments is identical regardless of whether they strike a deal or not. And for any high initial marginal cost, the joint profit increases to a higher level provided the patenting system is very strong (including complete patent protection). Interestingly, when the initial marginal cost is sufficiently high, there is now a multiplicity of patent agreements in the NBS. This is because the joint payoff characterised by a monopolist profit is unaffected for any α. Therefore, some (but not necessarily the complete) degree of patent protection is efficient.

Given the level of patent protection α^N in the NBS, the following results are an immediate consequence to Proposition 3.1. and Figure 3.2 depicts the equilibrium transfer payment T^N as a function of $\bar{c}$.

Corollary 3.1 [Equilibrium Transfer Payment in the NBS]

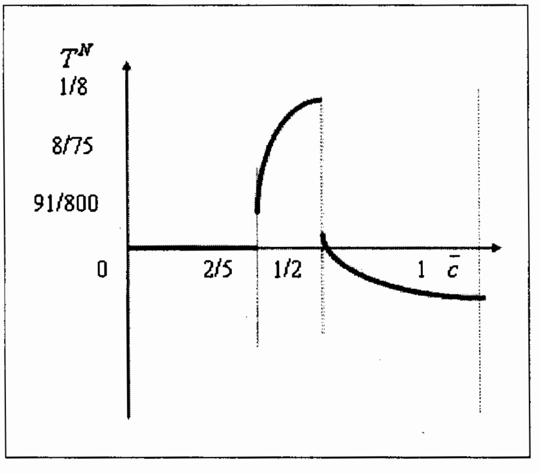
(a) *If* $\bar{c}\in(0,2/5]$, *then* $T^N=0$;

(b) *If* $\bar{c}\in[2/5,1/2)$, *then* $T^N=\bar{c}(2-\bar{c})/6$; *and*

(c) *If* $\bar{c}\in[1/2,1)$, *then* $T^N=(41-32\bar{c}-9\bar{c}^2)/200$.

Proof: See Appendix B.

Figure 3.2



Crucial to the results derived above is the assumption that governments negotiate on behalf of domestic firms over the degree of patent protection. Notice that governments, in contrast to private firms, are able to provide a credible promise of the level of patent protection. If we interpret the value of α as a patenting parameter capturing the effort committed to *patenting* across borders, e.g., the 'agreed' number of inspectors recruited to police the infringement of intellectual property rights, then an application of Corollary 3.1 to the issues of TRIPs suggest that whether it is worth attempting to reach agreement on IPR enforcement depends crucially on the cost of the research innovation.

Another emerging from these results suggests that the nature of intellectual property products should be taken into account while negotiating over an adequate level of protection. Even though a stronger patent may protect the innovating firm in the developed countries from losing its profit to the imitating firms in the less developed countries, the production cost of manufacturing IP products can vary, and, thus, has a signicant impact on the bargaining outcome. For example, given inventions that require low cost, governments need not at all negotiate over its protection, since, in the NBS, zero patent protection and zero side payment is an efficient outcome for low initial marginal cost. But if the production costs of IP products are high, then it makes sense for the governments involved in the trade dispute to try to reach an agreement over the protection of such intellectual property rights. Evidently, the transfer payment also rises with the cost of innovation. This is because government I's utility (as represented by the sum of firm I's profit and the amount of transfer payment) deteriorates when both cost and patenting protection are high. And for high $\bar{c}$ (i.e., $\bar{c} \in [1/2,1)$), the transfer payment in the NBS decreases in the initial marginal cost. This is because a monopoly market structure emerges in equilibrium, and, thus, cross-border patent protection is no longer an important issue as it would have been otherwise. Thus, in the NBS, only a smaller amount of transfer payment is paid to government I.

The Effect of Cheating

This section considers a situation in which the agreed level of patent enforcement may not be honestly implemented to its full extent. More specific, for any level of patent protection agreed at the negotiating table, the actual implemented degree of patent protection does not always coincide with the agreed one. This could happen for a number of reasons, for example, the imitating firm could lobby, ex-post, its government not to fully implement the patenting agreement; or the imitating government itself is corruptible. Thus, we assume that the possibility of cheating (as captured by λ) by government I (and thus government R's distrust) is common knowledge.

In order to explore the implication of this distinction between an 'agreement' and its actual 'implementation', and to study the effect of distrust on the level of patent enforcement in the NBS, we study a linear example and we assume that the actual implemented value, α^P, is a function of the agreed level α, where $\alpha \in [0,1]$, i.e., $\alpha^P = f(\alpha)$[11], that $\alpha^P = f(\alpha) \geq \alpha$, where $f'(\alpha) > 0$ and $f''(\alpha) \leq 0$, and that $f(1) = 1$, implying no cheating by G_I when there is no patent agreement. Since a greater means relatively lax patent protection regime, the actual implemented level of patent protection is, thus, greater than the agreed one. Suppose the implemented degree of patent enforcement is given by:

$$\alpha^P = f(\alpha) = (1-\lambda) + \lambda\alpha, \tag{10}$$

where $0 \leq \lambda \leq 1$ captures the extent to which the 'agreed' patent enforcement is being actually implemented. The value of λ can be interpreted as the degree of confidence in which G_R has about G_I's honesty while implementing the agreed patent protection. If, $\lambda = 1$ then G_R has full confidence in G_I honestly implementing the agreed patenting level; and if $\lambda = 0$, then G_R has no trust at all that G_I enforces the agreement of patent protection. And intermediate values of λ $(0 < \lambda < 1)$ suggest that G_R has only some confidence in G_I implementing the agreed patent protection. Alternatively, (10) may be interpreted as follows: with probability λ, G_I implements the agreed (α) level of patent protection, and with probability $1-\lambda$, G_I enforces no patent protection ($\alpha = 1$).

The Bargaining Equilibrium with Distrust

Proposition 4.1 below characterises the level of 'agreed' patent enforcement, α_d^N, in the NBS with distrust.

Proposition 4. 1 [Efficient Intellectual Property Protection with Distrust]
For any $0 \leq \lambda \leq 1$ and $0 < \bar{c} < 1$,

(a) *if* $0 < \lambda\bar{c} \leq 2/5$, *then* α_d^N *;*
(b) *if* $2/5 \leq \lambda\bar{c} < 1/2$, *then ;* $\alpha_d^N = 0$ *and*
(c) *if* $1/2 \leq \lambda\bar{c} < 1$, *then* $\alpha_d^N \in [0, 1 - 1/2\lambda\bar{c}]$.

Proof: See Appendix C.

And Corollary 4.1, which follows immediately from Proposition 4.1, characterises the transfer payment in the NBS with distrust.

Corollary 4.1 :[Equilibrium Transfer Payment with Distrust]
For any $0 \leq \lambda \leq 1$ and $0 < \bar{c} < 1$,

(a) *if* $0 < \lambda\bar{c} \leq 2/5$, *then* $T_d^N = 0$;
(b) *if* $2/5 \leq \lambda\bar{c} < 1/2$, *then* $T_d^N = \lambda\bar{c}(2 - \lambda\bar{c})/6$;
(c) *if* $1/2 \leq \lambda\bar{c} < 1$, *then* $T_d^N = (41 - 32\bar{c} - 9\bar{c}^2)/200$.

Proof: See Appendix C.

A straightforward comparison of the results with Proposition 3.1 suggests that distrust hampers bargaining outcomes, that is, the impact of trust/honesty/*ex post* lobbying on the actual patent enforcement should be taken into account while seeking an 'internationally-accepted' standard of patent protection in the multilateral forum of trade negotiations.

If we interpret the value of λ as the impact of ex post lobbying on the actual implementation of patent enforcement, then Proposition 4.1 suggests that important factors, such as the *ex post* lobbying, may lead the imitating government to cheat while implementing an agreed level of patent protection, even though two negotiating governments have struck a deal over intellectual property protection. Alternatively, if λ is interpreted as G_R's subjective evaluation of the extent to which G_I honestly implements the agreed level of patent enforcement, i.e., it confidence, then the subjective evaluation of G_R about its counterpart's honesty (or the degree of trust) plays an important role in influencing the negotiated outcome in the NBS - the agreed level of patent protection and the amount of transfer payment. The results also explain why imitators may dislike transparency of patent enforcement: more inspection by researching country may decrease side payment. On the other hand, more trust raises the likelihood of agreement, hence the reception of a transfer payment.

Intuitively, the two governments need not reach an agreement in the absence of trust, that is, it becomes more difficult to strike a deal between the governments when the value of λ is low. Hence, when government *R* has little confidence in government *I* enforcing the patent agreement, the two governments need not strike a bargain over the degree of patent protection.

Figure 4.1 below characterises α_d^N as a function of $\bar{c}$ and λ.

Figure 4.1

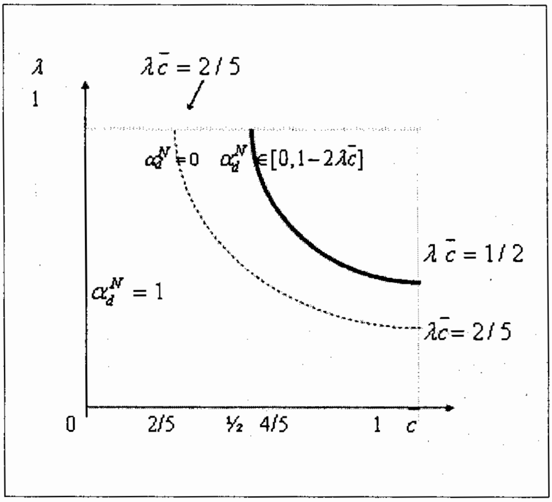


Figure 4.1 shows that the degree of trust in negotiations influences the bargaining outcome by changing the area within which the efficient level of patent protection applies (in other words, the boundaries for the negotiated outcome are now affected), that for any sufficiently low degree of trust, the two governments no longer agree to a multiplicity of patent agreements in the NBS, and that bargaining impasse, i.e., the two governments do not reach agreement, is likely to occur regardless the magnitude of initial marginal cost when the degree of trust is sufficiently low (i.e., $0 \le \lambda < 2/5$). Notice that $\bar{c}$-axis is now replaced by $\bar{c}\lambda$-axis, that cut-offs at $\lambda = 1$ correspond to Figure 3.1, and that the interval of $\bar{c}$ in which no patenting is agreed upon increases (since $\lambda\bar{c} \le \bar{c}$).

Conclusions

We have studied the negotiations over 'agreed' level of intellectual property protection across borders between two sovereign governments. The analyses have shown that, even in a wider context of multilateral trade negotiations, there are circumstances under which governments need not strike a deal over the level of patent protection (i.e., the governments can agree to zero patenting in the NBS). For example, when the governments negotiate on behalf of an industry producing the intellectual property products at very low cost, they need not strike any patenting agreement since there are no further gains from such agreement. And for high-cost industry, the two governments may engage in trade negotiations and try to reach a deal over the degree of patent protection. Furthermore, as the initial marginal cost rises, the two governments seek to reach patent agreement in a way such that the agreement even allows the innovating firm R to be a monopolist in the product market. Consequently, the agreement is characterised by a multiplicity of possible sufficiently strong patent agreements. The results have major policy implications: when the initial marginal cost is low, patent protection neither influences the firms' profits nor the utility of the governments. Hence, there is no need for governments to try to strike a deal over the protection of IP products. As the initial marginal cost increases, trade negotiations can facilitate the gains from reaching a patent agreement. Thus, the two governments try to strike a deal characterised by complete patent protection.

An observation of these results suggests that the analyses captures the dynamic aspect of R&D in reducing production cost: when the production cost is sufficiently high prior to the R&D phase, the multiple outcome of the patent agreements reflects that the monopolistic innovating government has the entire market share and thus welcomes a strong (not necessarily the complete) degree of patent protection. As the production cost decreases along the process of industrial innovation, governments become very sensitive to the degree of protection over intellectual property rights. This is because the innovating government begins to lose the market share to the imitator and thus, it demands a complete patent protection to compensate its losses arising from technology copying. Further, when the production cost becomes even lower as a consequence of process innovation, the technology embodied in the intellectual property products is widely diffused and the industries concerned can no longer extract any surplus from patenting. Naturally, zero protection is the efficient degree of patent.

We have also shown that, when the government representing an imitating firm that is strongly in favor of side payment to improve its utility, a complete patenting tends to occur and the government representing the innovating firm can easily strike a deal with its counterpart. Nevertheless, the question of whether the imitating government is to implement honestly the agreed level of patent protection remains unclear. It could possibly be the case that, by hastily agreeing to a complete patent protection, the imitating government can successfully extract foreign side payment. Once an agreement is signed, the officials may nevertheless be tempted to infringe. Consequently, trust plays a major role in influencing the bargaining outcome.

To conclude, the major policy implications of the analyses for the international negotiations over trade-related intellectual property rights are as follows. First, there is no need for patent negotiation when the initial marginal cost of the specific industries involved in production is sufficiently low. Second, the changes in policy objectives of the government concerned should be taken into account, especially when some of the imitating governments in negotiations prefer side payments to the profit of the imitating firms. And third, distrust in negotiations could lead to bargaining impasse, therefore, the issues of trust should also be considered while negotiating over an adequate level of patent protection in the multilateral trade negotiations.

NOTES

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[1] See, for instance, Aoki and Prusa (1993), D'Aspremont and Jacquemin (1988), DeBondt et al. (1992), Suzumura (1992), and Žigić (1998, 2000).

[2] By this assumption, we are able to provide a simplified analysis by assuming away the consumers surplus.

[3] We emphasise the aspect that '... often important information leaks out already during the development process' (Helpman, 1993, p. 1247), even though an alternative Stackelberg game in the R&D stage may characterise the time lag between research innovation and imitation.

[4] We adopt here a specific cost structure to bring out the essence of the relations between patenting system and the efficiency of R&D process. Similar formulations are widely used elsewere; see, for instance, Chin and Grossman (1990), and Žigić (1998).

[5] We thank the anonymous referee for pointing out this issue and the resulting implications for our analyses. Elsewhere (Tsai and Chen, 2004), we have incorporated into our analyses the role of research efficiency with an alternative specific, rathen than general, specification of the 'R&D production function'. By investigating the nature of research efficiency and the industry to which it can be meaningfully applied, we show the robustness of our results without having to resort to a general formulation.

[6] We thank the anonymous referee for pointing out the role of the 'market size' parameter and its implications for the market outcomes. Since the present study focuses on the optimal research investment with spillovers, we, thus, present a simple, standard model to extract some important qualitative results. Readers interested in the issue of market size and its impact should read Žigić (1998, 2000).

[7] The government is considered an agent that is able to negotiate on behalf of its domestic firm should the latter get involved in any trade dispute. Spencer and Brander (1983) justify this formulation by arguing government's pre-commitment in *R&D* and output subsidies.

[8] See Muthoo (1999) for an interesting elaboration on the issues of bribery and the control of crime.

[9] The nature of the bargain differs if were interpreted as an information sharing parameter. That is, if the value of α is explained as the extent to which firm R discloses the $R\&D$ output (or transfers the

technology) to its rival in the product market, then the parameter T should represent a license fee paid by the imitating government I.

[10] This is justified by Binmore, Rubinstein and Wolinsky (1986), who show that the unique sub-game perfect equilibrium of Rubinstein's alternating-offer model implements the NBS.

[11] We have studied, in Section 3, the case of $\alpha^P = f(\alpha) = \alpha$, which implies that cheating in patent enforcement does not take place because the implemented level of patent enforcement is identical to the agreed one.

[12] This is very common in many other applications, e.g. Hendriks, Keen and Muthoo (1998). In the present context, the parameter α defines the efficient level of patent protection and T characterizes the distribution of gains from striking an agreement between G_R and G_I.

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Appendix A: proof to Proposition 2.1

In order to prove this proposition we first need to establish several preliminary results, which are organised into two lemmas.

Lemma A. 1. For any $h \geq 0$, c_R and c_I, the Nash equilibrium (NE) output levels in the Cournot sub-game, denoted by $\{y_R^*, y_I^*\}$, are (i) $y_R^* = \dfrac{(1-c_R)}{2}$ and $y_I^* = 0$, for any h such that $c_I \geq (1+c_R)/2$; and (ii) $y_R^* = \dfrac{(1-2c_R+c_I)}{3}$ and $y_I^* = \dfrac{(1-2c_I+c_R)}{3}$ for any h such that $c_I < (1+c_R)/2$.

Proof. For any $h \geq 0$, c_R and c_I are defined by (1) and (2) respectively. Notice that $0 \leq c_R \leq c_I \leq \bar{c}$. Hence, for any output of firm j ($y \geq 0$), firm i's best (output) response function, $R_i(y_j)$, where $i, j = R, I$ and $i \neq j$, is given by:

$$y_i = R_i(y_j) = \begin{cases} (1-c_i-y_y)/2, if\ y_j < 1-c_i \\ 0 \qquad\qquad ,if\ y_j \geq 1-c_i \end{cases} \tag{A.1}$$

Solving (A.1) for $\{y_R^*, y_I^*\}$, we have, (i) for any h such that , $c_I \geq (1+c_R)/2$, $y_R^* = \dfrac{(1-c_R)}{2}$ and $y_I^* = 0$; and (ii) for any h such that , $c_I < (1+c_R)/2$, $y_R^* = \dfrac{(1-2c_R+c_I)}{3}$ and $y_I^* = \dfrac{(1-2c_I+c_R)}{3}$.

Lemma A. 2.

(a) *For any* $0 < \bar{c} < 1$ *and* $0 \leq \alpha \leq 1/2$, $h^* = \bar{h} = \bar{c}^2/4$.

(b) *If* $0 < \bar{c} \leq 4/9$ *and* $1/2 < \alpha \leq 1$, *then* $h^* = \bar{h} = \bar{c}^2/4$.

(c) If $4/9 < \bar{c} < 1$, then there exists an $\alpha^* > 1/2$ such that

(i) $\forall\ \ 1/2 < \alpha \leq \alpha^*$, $h^* = \bar{h} = \bar{c}^2/4$; and

(ii) $\forall\, \alpha^* < \alpha \leq 1$, $h = \tilde{h}$ where $\tilde{h} = \left(\dfrac{(4-2\alpha)(1-\bar{c})}{(2\alpha-1)(7-2\alpha)}\right)^2$ is the unique solution to $\dfrac{d\pi_R(h^*)}{dh} = 0$.

Proof. (a) Using (1), it is evident that for any $h > \bar{c}^2/4, \pi_R^*(h) < \pi_R^*(\bar{c}^2/4)$. Hence, for any $h \geq 0$, firm R's problem is to solve $\max\limits_{0 \leq h \leq \bar{h}} \pi_R^*(h)$ where $\bar{h} = \bar{c}^2/4$. For any $0 \leq h \leq \bar{h}$, $c_R = \bar{c} - 2\sqrt{h}$ and . Hence, for any $0 \leq h \leq \bar{h}$, we have

$$\frac{\partial c_R}{\partial h} = -\frac{1}{\sqrt{h}} \text{ and } \frac{\partial c_I}{\partial h} = -\frac{\alpha}{\sqrt{h}} \tag{A2.1}$$

$$\left.\begin{array}{l}\dfrac{dy_R^*}{dh}=-\dfrac{1}{2}\dfrac{\partial c_R}{\partial h}=\dfrac{1}{2\sqrt{h}}\\ \dfrac{dy_I^*}{dh}=0\end{array}\right\}\quad \forall \quad h\ s.t.\ c_I\geq(1+c_R)/2 \tag{A2.2}$$

$$\left.\begin{array}{l}\dfrac{dy_R^*}{dh}=\dfrac{1}{3}\left[-2\dfrac{\partial c_R}{\partial h}+\dfrac{\partial c_I}{\partial h}\right]=\dfrac{(2-\alpha)}{3\sqrt{h}}\\ \dfrac{dy_I^*}{dh}=\dfrac{1}{3}\left[-2\dfrac{\partial c_I}{\partial h}+\dfrac{\partial c_R}{\partial h}\right]=\dfrac{(2\alpha-1)}{3\sqrt{h}}\end{array}\right\}\quad \forall\ h\ s.t.\ c_I<(1+c_R)/2 \tag{A2.3}$$

Since $\dfrac{\partial\pi_R(y_R^*,y_I^*,c_R,h)}{\partial y_R}=0$, we have

$$\frac{d\pi_R^*}{dh}=\underbrace{\left[\frac{\partial\pi_R}{\partial c_R}\frac{\partial c_R}{\partial h}+\frac{\partial\pi_R}{\partial h}\right]}_{direct\ effect}+\underbrace{\left[\frac{\partial\pi_R}{\partial y_I}\frac{\partial y_I^*}{\partial h}\right]}_{strategic\ effect} \tag{A3}$$

where $\dfrac{\partial\pi_R}{\partial y_I}=-y_R$, $\dfrac{\partial\pi_R}{\partial c_R}=-y_R^*$ and $\dfrac{\partial\pi_R}{\partial h}=-1.$

Using (A2.1)-(A2.3) and rearranging, we have

$$\frac{d\pi_R^*}{dh}=\frac{(1-\bar{c})}{2\sqrt{h}}\quad \forall\ h\ s.t.\ c_I\geq(1+c_R)/2 \tag{A4.1}$$

$$\frac{d\pi_R^*}{dh}=\frac{E}{\sqrt{h}}+F\quad \forall\ h\ s.t.\ c_I<(1+c_R)/2 \tag{A4.2}$$

where $E=2(2-\alpha)(1-\bar{c})/9$ and

$$F=\frac{4(2-\alpha)}{9}-1\begin{cases}>0, if\ \alpha<1/2\\ =0, if\ \alpha=1/2\\ <0, if\ \alpha>1/2\end{cases}$$

It is clear, from (A4.1), that, if h is such that $c_I\geq(1+c_R)/2$ (i.e., $2(1-2\alpha)\sqrt{h}\geq(1-\bar{c})$), then the total effect is strictly positive for any $0\leq\alpha\leq 1/2$. Moreover, for any h such that $c_I<(1+c_R)/2$, then the total effect is also strictly positive for any $0\leq\alpha\leq1/2$. Hence, we have proved the result contained in Lemma A.2(a).

(b) For any $\alpha > 1/2$, the choice of h gives rise only to a duopolistic market structure. The total effect is, however, ambiguous. Hence, for any $0 \le h \le \bar{h}$, let us evaluate firm R's marginal profit at . We have, using (A4.2), and rearranging

$$\left.\frac{d\pi_R^*}{dh}\right|_{h=\bar{h}} = \frac{4(2-\alpha)\left[1+\bar{c}(1-\alpha)\right]}{9\bar{c}} - 1. \tag{A.5}$$

Notice that

$$\left.\frac{d\pi_R^*(h)}{dh}\right|_{h=\bar{h}} \underset{<}{\overset{>}{-}} 0 \text{ if and only if } Z \underset{<}{\overset{>}{-}} 0, \tag{A.6}$$

where $Z = \bar{c}\alpha^2 - (1+3\bar{c})\alpha + (2 - \bar{c}/4)$.

Z is a quadratic function of α which attains a minimum at $\alpha = (1+3\bar{c})/2\bar{c} > 1$ and is strictly decreasing in α over the closed interval [0, 1]. Moreover, it is clear that $Z(0) > 0$ and $Z(1) = 1 - 9\bar{c}/4$. Therefore, $Z(1) \ge 0$ if and only if $\bar{c} \le 4/9$. This implies if $\bar{c} \le 4/9$, then $\left.\frac{d\pi_R^*}{dh}\right|_{h=\bar{h}} \ge 0$. Hence, we have proved the result contained in Lemma A.2(b).

(c) For any $1/2 < \alpha \le 1$, the equilibrium market structure is always duopoly and if $\bar{c} > 4/9$, then $Z(1) < 0$. Notice that $Z(1/2) = 3(1-\bar{c})/2 > 0$. Hence, there exists a $\alpha > 1/2$ such that for any $\alpha \in \left(\alpha^*, 1\right]$, $Z(\alpha) < 0$; and, for any $\alpha \in \left(1/2, \alpha^*\right]$, $Z(\alpha) \ge 0$, where $\alpha^* = \left[(1+3\bar{c}) - \sqrt{1 - 2\bar{c} + 10\bar{c}^2}\right]/2\bar{c}$. Hence, we have proved the result contained in Lemma A.2(c).

Appendix B: proofs to Proposition 3.1 and Corollary 3.1

Proof to Proposition 3.1

To prove this proposition, we proceed in three steps:

Step 1. We need to derive the Pareto efficient frontier of the set Ω. Since the NBS is Pareto efficient, the agreement (α^N, T^N) in the NBS maximises one player's utility subject to the other player receiving a fixed level of utility. Hence, (α^N, T^N) must be a solution to:

$$\underset{\alpha\in[0,1],\, T\in\Re}{Max}\ \pi^*_R(\alpha)-T \tag{B.1}$$

where $\bar{u}_I$ is some fixed utility level for GI.

Step 2. We now characterise the solutions to (B.1). We first argue the constraint binds at the optimum. In the NBS, (α^N, T^N), if the constraint does not bind (that is, $\pi^*_I(\alpha^N)+T^N \geq \bar{u}_I$), then G_R can reduce the amount of transfer payment offered (T^N) and still reach an agreement with G_I. The constraint, therefore, binds at the optimum. Hence, in the NBS, (α^N, T^N) is a solution to the following problem (after substituting for T in $U_R(\alpha, T)$ using $U_I(\alpha, T)=\bar{u}_I$):

$$\underset{0\leq\alpha\leq 1}{Max}\,\pi^*_R(\alpha)+\pi^*_I(\alpha)-\bar{u}_I\,. \tag{B.2}$$

Let $V^*(\alpha)$ denote the joint utility - $\pi^*_R(\alpha)+\pi^*_I(\alpha)-\bar{u}_I$ - when the two governments reach an agreement. Notice that the transfer payment, T, drops out in equation (B.1)[12].

Step 3. Lemma B.1 characterises the properties of $V^*(\alpha)$, which forms the basis of our analysis.

Lemma B.1 [The properties of $V^*(\alpha)$]

(i) *For any* $0<\bar{c}<1, V^*(\alpha)$, *is continuous on* $[0,1]$;

(ii) *For any* $0<\bar{c}<1/2, V^*(\alpha)$, *is strictly convex on* [0, 1];

(iii) *For any* $1/2\leq\bar{c}<1, V^*(\alpha)$, *is constant on* $[0, 1-1/2\bar{c}]$; *is strictly* convex on $(1-1/2\bar{c}, \alpha^*]$ and is strictly decreasing on $(\alpha^*, 1]$, where

$$\alpha^* = \left[(1+3\bar{c}-\sqrt{1-2\bar{c}+10\bar{c}^2}\right]/2\bar{c}.$$

Proof: By the proof to Proposition 2.1, it is straightforward, but tedious, to compute $V^*(\alpha)$ for any $0<\bar{c}<1$ and $\alpha\in[0,1]$ (Details for the derivation is available upon request).

Lemma B.1 implies that the sum of the profits $\pi^*_R(\alpha)+\pi^*_I(\alpha)$ is continuous and may (but need not) be strictly convex in α. Intuitively, this result is analogous to results in the theory of perfect competition that a firm's profit function is convex in prices. That is, although profit is a concave function of the choice variable of output, the maximised value may, in fact, be convex in a parameter (Varian, 1992, p. 41).

Notice that a strictly convex function defined on a closed interval achieves a maximum value at one of the end points of the interval. Hence, we solve for the degree of patent protection, α^N, in the NBS (after evaluating $V^*(\alpha)$ at the end points, given the value of the initial marginal cost) and have obtained the results.

Proof to Corollary 3.1

To prove Corollary 3.1, we proceed in two steps:

Step 1. By Proposition 3.1, for any $\alpha=\alpha^N$, the transfer payment, T^N, chosen in the NBS solves

$$\begin{aligned}&\underset{T}{Max}(U_R(\alpha^N,T)-d_R)(U_I(\alpha^N,T)-d_I)\\&s.t.\quad T\in\Re, U_R\geq d_R \text{ and } U_I\geq d_I\end{aligned}\tag{B.3}$$

where $U_i(\alpha^N,T)$, $i=R, I$, are defined in (6) and (7), $d_R=U_R(1{,}0)$ and $d_I=U_I(1{,}0)$.

A straightforward calculation for the first-order condition of the Nash product gives (i.e., let $\frac{dW}{dT}=0$ and rearranging for T):

$$T=\left[\pi^*_R(\alpha^N)-\pi^*_I(\alpha^N)-d_R+d_I\right]/2.\tag{B.4}$$

After substituting for T^N in $U_i(\alpha^N,T)$, $i=R, I$, as defined in (6) and (7), we obtain

$$U_i(\alpha^N,T^N)=d_i+\left[\pi^*_i(\alpha^N)+\pi^*_j(\alpha^N)-d_i-d_j\right]/2, i,j=R,I \text{ and } i\neq j.\tag{B.5}$$

Equation (B.5) implies that, in the NBS, each government's payoff must be greater than (or equal to) $d_R=U_R(1{,}0)$ and $d_I=U_I(1{,}0)$, that is, the payoffs if the parties fail to reach agreement. Moreover, the 'surplus' (i.e., the terms in brackets in equation (B.5)) is split equally. This is just re-discovery of the well-known 'split-the-difference' rule (cf. Sutton 1986).

Step 2. By the proof to Proposition 2.1, we can also compute, for any $\alpha=\alpha^N$, the transfer payment, T^N, for any $0<\bar{c}<1$ (The details are available upon request).

Appendix C: Proofs to Proposition 4.1 and Corollary 4.1

Proof to Proposition 4.1

To prove this proposition, using the results contained in Lemma B.1 and Equation (10), we have

$V^*(\cdot) \equiv V_m^*(\alpha) = (1-\bar{c}^2)/4$ for any $1/2 \le \bar{c} < 1, 1/2 \le \lambda \le,$ and $0 \le \alpha \le \beta^m$;

$$V^*(\cdot) \equiv V_1^*(\alpha,\lambda) = \frac{\left[2-2\lambda(1-\alpha)\bar{c}+5\lambda^2(1-\alpha)^2\bar{c}^2\right]}{9} - \frac{\bar{c}^2}{4}$$ for any $0 < \bar{c} < 1$,

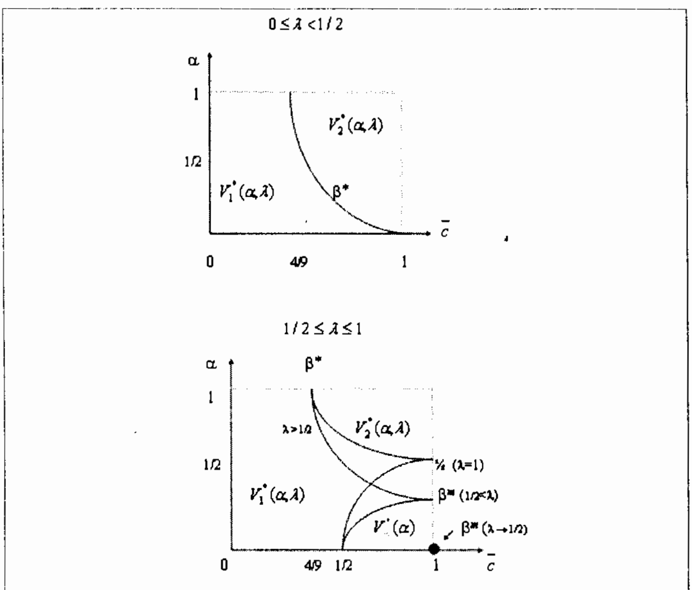
$0 \le \lambda \le 1$ and $\max\left\{0,\beta^m\right\} < \alpha \le \min\left\{1,\beta^*\right\}$; and

$$V^*(\cdot) \equiv V_2^*(\alpha,\lambda) = \frac{(1-\bar{c})^2\left[14-4\lambda(1-\alpha)-20\lambda^2(1-\alpha)^2-8\lambda^3(1-\alpha)^3\right]}{\left[1-2\lambda(1-\alpha)\right]\left[5+2\lambda(1-\alpha)\right]^2}$$ for any

$4/9 < \bar{c} < 1, 0 \le \lambda \le 1,$ and $\beta^* < \alpha \le 1$.

where $\beta^m = 1-(1/2\lambda\bar{c})$ and $\beta^* = 1-(1-\alpha^*)/\lambda$.

The following figures characterise $V^*(\cdot)$. Notice that if $0 \le \lambda < 1/2$, then there can be no $V_m^*(\alpha)$ for any $0 < \bar{c} < 1$ and $0 \le \alpha \le 1$.



For any $0<\bar{c}<1$ and $0\le\lambda\le 1$, $\pi_R^*(\alpha)$ and $\pi_I^*(\alpha)$ are continuous in α on [0, 1], in particular, is not discontinuous at $\alpha=\alpha^*$. Hence, for any $0<\bar{c}<1$ and $0\le\lambda\le 1$, $V^*(\cdot)$ is continuous in α on [0, 1].

Clearly, for any $1/2\le\bar{c}<1$, if $1/2\le\lambda\le 1$, then $V_m^*(\alpha)=(1-\bar{c}^2)/4$ is a constant over $0\le\alpha\le\beta^m$.

Differentiating $V_1^*(\alpha,\lambda)$ with respect to α, we have,

$$\frac{dV_1^*(\alpha)}{d\alpha}=\frac{2\lambda\bar{c}\left[1-5\lambda\bar{c}(1-\alpha)\right]}{9} \text{ and}$$

$$\frac{d^2V_1^*(\alpha)}{d\alpha^2}=\frac{10\lambda^2\bar{c}^2}{9}>0.$$

Hence, for any $0\le\lambda\le 1$ and $0<\bar{c}<1$, $V_1^*(\alpha,\lambda)$ is strictly convex in α on $\left[0,\beta^*\right]$.

Further, differentiating $V_2^*(\alpha,\lambda)$ with respect to α, we have,

$$\frac{dV_2^*(\alpha)}{d\alpha}=\frac{2\lambda(1-\bar{c})^2}{A^2}\left(\frac{(B-A}{B^2}-\frac{2C}{A}\right)<0;$$

$$\frac{d^2V_2^*}{d\alpha^2}=\frac{8\lambda^2(1-\bar{c})^2}{A^3}\left(\frac{A^2+(B-A)\left[A(B-A)+2B^3\right]}{AB^3}\right)>0$$

where $A=\left[5+2\lambda(1-\alpha)\right]$, $B=\left[1-2\lambda(1-\alpha)\right]$, and $C=\left[3+2\lambda(1-\alpha)\right]$.

Hence, for any $0\le\lambda\le 1$ and $0<\bar{c}<1$, $V_2^*(\alpha,\lambda)$ is strictly convex and strictly decreasing in α on $\left(\beta^*,1\right]$. This establishes the properties of $V^*(\cdot)$.

Suppose $0\le\lambda\le 1/2$. Since $V^*(\cdot)$ is continuous, $V_1^*(\alpha,\lambda)$ is strictly convex in α on $\left[0,\beta^*\right]$, $V_2^*(\alpha,\lambda)$ is strictly convex and strictly decreasing in α on $\left(\beta^*,1\right]$ for any $0<\bar{c}<1$. Hence, evaluating $V_1^*(\alpha,\lambda)$ at $\alpha=0$ and $\alpha=1$ respectively, we have, $V_1^*(0)=(2-2\lambda\bar{c}+5\lambda^2\bar{c}^2)/9-\bar{c}^2/4$ and $V_1^*(1)=2/9-\bar{c}^2/4$.

A straightforward calculation shows that $V_1^*(0)<V_1^*(1)$ if and only if $\lambda\bar{c}<2/5$. Hence, for any $0\le\lambda\le 1/2$ and $0<\bar{c}<1$, if $0<\bar{c}\le 2/5\lambda$, then $\alpha_d^N=1$, and if $2/5\lambda\le\bar{c}<1/2\lambda$, then $\alpha_d^N=0$. This establishes the results in Proposition 4.1 (a) and (b).

Now suppose $1/2 \le \lambda \le 1$. The joint payoff $V_m^*(\alpha)$ is a constant over $[0,1-(1/2\lambda\bar{c})]$ for any $1/2 \le \bar{c} < 1$. Notice that $V_m^*(\alpha)$ is greater than both $V_1^*(\alpha,\lambda)$ and $V_2^*(\alpha,\lambda)$, since the monopolist profit is higher than the duopolist profit. Moreover, $V_1^*(\alpha,\lambda) > V_2^*(\alpha,\lambda)$ for any $\beta^m < \alpha \le 1$. Hence, for any $1/2 \le \bar{c} < 1$ and $1/2 \le \lambda \le 1$, we evaluate $V_m^*(\alpha)$ and $V_2^*(\alpha,\lambda)$, a straightforward calculation shows that $V_m^*(\alpha) > V_2^*(\beta^*)$ since $0 > 5\lambda^2 d^2 - 2(5\lambda^2 + 2\lambda)d - (1+\lambda)(1-5\lambda)$, where

$d = \sqrt{1-2\bar{c}+10\bar{c}^2} - \bar{c}$. Therefore, for any $1/2 \le \bar{c} < 1$, $1/2 < \lambda \le 1$ and $1/2 < \lambda\bar{c} < 1$, $\alpha_d^N \in [0,1-1/2\lambda\bar{c}]$. This establishes the result contained in Proposition 4.1 (c). The proof for Proposition 4.1 is now complete.

Proof to Corollary 4.1

Intuitively, for any $0 < \bar{c} \le 2/5\lambda$, if $\alpha_d^N = 1$, then $T_d^N = 0$. Hence, this establishes the results contained in Corollary 4.1 (a)

After substituting $\alpha_d^N = 0$ into (B.5), we have $\pi_R^*(0) = (1+2\lambda\bar{c}+\lambda^2\bar{c}^2)/9 - \bar{c}^2/4$, $\pi_I^*(0) = (1-4\lambda\bar{c}+4\lambda^2\bar{c}^2)/9$, $d_R = 1/9 - \bar{c}^2/4$ and $d_I = 1/9$. Hence, for any $2/5\lambda \le \bar{c} \le 1/2\lambda$, $T_d^N = \lambda\bar{c}(2-\lambda\bar{c})/6$. This establishes Corollary 4.1 (b).

For any $1/2 \le \bar{c} < 1$, $1/2 < \lambda \le 1$ and $1/2 < \lambda\bar{c} < 1$, the equilibrium market structure is characterised by a monopolist profit. Hence, we have, after substituting any value, e.g., $\alpha_d^N = 0$, of $\alpha_d^N \in [0,1-1/2\lambda\bar{c}]$, into (B.5), $\pi_R^*(0) = (1-\bar{c}^2)/4$, $\pi_I^* = 0$, $d_R = (1-\bar{c})^2/5$ and $d_I = 9(1-\bar{c})^2/25$. A straightforward calculation shows that the equilibrium transfer payment in the NBS with distrust is $T_d^N = (41-32\bar{c}-9\bar{c}^2)/200$. This establishes Corollary 4.1(c). The proof for Corollary 4.1 is now complete.